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# LECTURES

ON THE

# ELEMENTS OF BOTANY.

## PART I.

CONTAINING

THE DESCRIPTIVE ANATOMY OF THOSE ORGANS, ON WHICH THE GROWTH AND PRESERVATION OF THE VEGETABLE DEPEND.

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BY

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TO

THE PRESIDENT AND THE FELLOWS

OF

THE ROYAL COLLEGE OF PHYSICIANS,

OF LONDON;

IN THE HOPE

THAT

THEIR AVOWED PATRONAGE

OF

AN ELEMENTARY WORK ON BOTANICAL SCIENCE,

WILL PROMOTE THE FUTURE STUDY

OF

THAT BRANCH OF KNOWLEDGE

AS A PART OF MEDICAL EDUCATION;

AND THAT,

BY THUS DISPLAYING THEIR APPROBATION

OF

WHATEVER CAN ENLARGE THE VIEWS

OF THE STUDENT

IN

THE INVESTIGATION OF ORGANIC LIFE,

THE CHARACTER

OF THE MEDICAL PHILOSOPHER

MAY BE ELEVATED TO ITS DUE RANK IN SOCIETY;

THESE LECTURES,

WITH THEIR GRACIOUS PERMISSION,

ARE INSCRIBED

BY

THE AUTHOR.



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# PREFACE.

NUMEROUS works on the elementary principles of Botany, and many of them very excellent productions, have been published, both in this country and on the continent, within the last twenty years: and, by pointing out the mode of investigating the laws of vegetable life, have done much to remove an objection to the study of Botanical science, which had long prevailed, "that "it is a pursuit that amuses the fancy and exercises the memory, without improving the mind "or advancing any real knowledge *." Under these circumstances, the publication of a new work on this subject may require some apology; and it was not my intention to have placed the following Lectures before the public, had I not accidentally met with a manuscript copy of them,

* *White's Nat. Hist. of Selborne*, 8vo. London, 1822, vol. ii. p. 38.

as they were delivered to my pupils, exposed for sale in a bookseller's shop. Reflecting, therefore, that any peculiar theories connected with vegetable physiology, which I had taught, and of which little more than outlines had been sketched for the class-room, were likely to be much misrepresented, and even that many of the facts taken from authors might be misstated, justice to my reputation required that I should rather publish my own opinions, than run the hazard of their getting into the press in a mutilated condition. In revising my manuscript, however, for this purpose, I found that the view of the subject opened before me, that one investigation led on to another; and that a frequent appeal to Nature forced me to reject much of what I had formerly regarded as truth; so that the work imperceptibly extended far beyond the limits I had allotted to it; and, now, retains little more than the name and the arrangement of the original Lectures.

The present volume treats of the forms and the anatomy of those organs which are necessary for the growth and the preservation of the vege-

table individual; and, although it does not profess to enter fully into the explanation of the laws which regulate the functions of these organic structures, yet, much of physiology has been introduced, both to illustrate the descriptions, and to relieve the dryness of the anatomical details. The necessity of an accurate knowledge of structure, will be fully perceived in the perusal of the physiological discussions which are intended to form the subject of the second volume. I trust that the plan of illustrating the descriptions by the introduction of cuts into the body of the letter-press, will be found of considerable assistance to the student; and that the engraved plates, although not all of equal merit in point of execution, will, nevertheless, be found sufficient for conveying correct ideas of those parts, which, from their minuteness, are necessarily microscopic objects.

As an apology for errors which may be detected in the volume, I might plead the interruptions, anxieties, and unremitting duties of very extensive professional occupations; but, as I am aware that no author is dragged before the tribunal of

the public against his inclination, and until he declares himself prepared for trial, I do not think such circumstances valid reasons for lenity or favour. The work, therefore, is published without any claim of indulgence, but with a conviction, that, although many objections may be raised to the doctrines it contains, yet, if it have merit, that its faults will be lightly handled; and if it be undeserving of approbation, that even the countenance of the learned body, under whose patronage it is sent forth, cannot alter the sentence which Justice should dictate.

ANTHONY TODD THOMSON.

91, *Sloane Street*,
*May* 30, 1822.

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10. Cuticle of the superior disk of Rumex *acetosa: a.* cuticular pore; *b.* lymphatic.

11. Transverse slice of a portion of the expansion of a leaf of Zea *Mays: a.a.* cuticle; *b.* the parenchyma or substance of the leaf; *c.c.* one of the visible costæ; *d.e.d.e.d.* fasciculi of vessels not visible on the surface of the leaf; *f.f.* two spaces, more cellular than the rest of the leaf, guarded on each side by short, subulate spines. (p. 561).

12. Transverse slice of the petiole of Trapa *natans: a.a.* the vacuities, which are filled with air; *b.b.b.* diaphragms which separate one vacuity from another, in the length of the petiole; *c.* vascular fasciculi occupying the centre of the petiole. (p. 596).

Fig. 13. One of the above-mentioned diaphragms separated; *a.* the cellular sides of the vacuity; *b.* the diaphragm, which is slightly convex on the exposed surface. (p. 596).

14. Portion of the cuticle of the leaf of Zea *Mays:* *a. a.* the cuticular or pneumatic pores; *b. b.* the lymphatic vessels. (p. 605).

15. Structure of the cuticular pore in the leaf of Zea *Mays.*

16. Transverse slice of a portion of the leaf of Hoya *carnosa:* *a.* the cutis of the superior, *b.* that of the inferior surface. (p. 590).

## CORRIGENDA.

***The reader is requested to make the following Corrections before commencing the perusal of the volume.***

Page 84, *l.* 12, for become *read* becomes.
87, *l.* 9, *dele* justly.
106, *l.* 12, *nota,* for occasions *read* occasion.
149, *l.* 21, between the words "in" and "formation," *put* "the."
178, *l.* 3 from bottom, for *b. read a.*
*ib. l.* 4 ———————, for *a. read b.*
238, *l.* 5, for Athemis *read* Anthemis.
266, *l.* 6, for Anœthera *read* Œnothera.
268, *l.* 25, for *setaceous* read *setaceosus.*
269, *l.* 2 from bottom, for 5 *read* 9.
270, *l.* 4, 16, 20, 25, for 5 *read* 9.
272, *l.* 6, 10, for 5 *read* 9.
288, *l.* 10, for Œnathe *read* Œnanthe.
392, *l.* 15, for 6 *read* 7. A.
409, *l.* 9, for * *put* †, and *l.* 21, for † *put* *.
416, *l.* 1, for *l. l. l. l. read b. b. b. b.*
424, *l.* 2 from bottom, for Plate 9 *read* Plate 8.
466, *l.* 20, for Plate 9 *read* Plate 8.
406, *l.* 18, for Dycotyledons *read* Dicotyledons.
432, *l.* 4, for stems *read* roots.
464, *l.* 5, for woody *read* woolly.
495, *nota,* for species *read* specimen.
494, *l.* 2, for cirrose *read* cirrhose.
501, *l.* 18, for shined *read* shining.
517, *l.* 16, for seveal *read* several.
561, *l.* 22 and 26, for fig. 13 *read* fig. 11.
562. *l.* 6, for fig. 13 *read* fig. 11.
564, *l.* 3, for "is a few proper vessels surrounded by," *read* "is surrounded by a few proper vessels."
597, *l.* 18, for fig. 14 *read* fig. 16.

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# LECTURES,

*&c. &c.*

## LECTURE I.

INTRODUCTION—SKETCH OF THE RISE AND PROGRESS OF BOTANY—UTILITY OF THE SCIENCE—METHOD OF STUDYING IT, AND PLAN OF THE COURSE.

GENTLEMEN,

In commencing a Course of Lectures on any branch of science, the Lecturer must necessarily regard his auditors as totally ignorant of the subject of which he is about to treat; and must endeavour not only to awaken their love for it, by conveying some idea of its nature, and the advantages to be derived from the study of it, but, by tracing its origin and progress, or entering into the details of its history, to elevate their ideas of its importance, by a display of the great and illustrious names that swell the catalogue of its votaries, and of the estimation in which it has been held by mankind in prior ages.



4

Whilst I acknowledge the propriety of this custom, I must at the same time observe, that, in following it, I do not intend to enter minutely into the history of the science we are about to investigate, but, tracing merely a sketch of the rise and progress of Botany, rather to excite your esteem for it by a display of its utility.

Botany derives its name from Βοτάνη, a Greek word which signifies an herb. It is that branch of Natural History which concerns vegetables; which teaches the knowledge of their structure, habits, and properties; and to distinguish different plants from each other *. That part of the science which treats of the structure, habits, and properties of plants, is particularly distinguished by the term PHYTOLOGY; that which refers to the classification of plants by their exterior characters, so that one species may be readily distinguished from another, is denominated SYSTEMATIC BOTANY. The knowledge of both of these parts is requisite to constitute a true Botanist. But it is further my intention, in this Course of Lectures, to enter upon a third branch, particularly interesting to those who desire to become acquainted with the economical and medicinal uses of plants; as it refers to their poisonous properties, and the ac-

* "Botanice est scientia naturalis, quæ *Vegetabilium* cog-"nitionem tradit." LINNÆUS, *Phil. Bot. Introduct.* § 4.

tion of vegetable poisons on the animal system. This branch of botanical science I would distinguish by the term VEGETABLE TOXICOLOGY.

In making a rapid sketch of the rise and progress of the science of Botany, I cannot avoid taking notice of that wonderful love of antiquity which seems to be so congenial to the human mind, that whatever bears the rust of past ages, appears to rise proportionally in the esteem of mankind. Hence every one is anxious to date the origin of the particular art or science which he professes, from the earliest times; and to increase the respect in which he would wish it to be held by impressing upon it the stamp of antiquity. Thus Tubal Cain has been regarded as the father of Chemistry, and Æsculapius that of Medicine: in the idle hours of the Egyptian shepherds, the sublime speculations of Astronomy are supposed to have commenced; and, if we were to indulge Fancy in her flights, we might with equal truth, perhaps, trace Botany to a period nearly coeval with the creation of the human race. But such conjectures, as they are vague and fanciful only, cannot be useful or satisfactory even as objects of simple curiosity; and it is impossible to say what was the state of the arts and the sciences in the early ages, the oral records of which, for we cannot suppose that any other existed, have long since passed away, and left imagination to fill

up the blank. More certain data for tracing the origin of art and science in the infancy of society have been afforded by the discoveries of modern circumnavigators. In those stages of it, which their labours have opened to our view, we perceive something like the fine arts, and some of the more useful sciences, awakening at a very early period. We behold Music, Poetry, Sculpture, and Painting, in their infant state, walking hand in hand with civilization; and, even before the savage has thrown aside the deer-skin and the club, their influence actuating his feelings and energies, and having a principal share in the formation of his character. We observe them kindling by degrees the social and benevolent affections in the human bosom; binding man to his native soil, by uniting agreeable associations with locality; forming the first medium of historical record; laying the foundation of government; exciting emulation; and sowing the seeds of patriotism. In this dawn of society, something like Botany is also to be seen. The plants which surround the human savage are the ornaments of the earth. Nature has bestowed upon them a great diversity of form, of magnitude, of colour, and of odour, equally fitted to attract the attention, to delight the senses, and to administer to the necessities of mankind. The umbrageous tree, therefore, under which uncivilized man shelters himself

from the ardour of the meridian blaze, the flower which charms his eye, and the fruit that allures and pleases his appetite, excite in him the desire of knowing them again; he marks some peculiar feature or characteristic which he observes in them; and by these they are ever after recognised. He even proceeds, in some degree, to name and to class them. Thus, whatever may be the language which is the medium of his ideas, he confers a name on a fruit which he has seen and tasted. Let us suppose the term he has employed to be *plum,* and that the fruit is of a green colour. In a short time, meeting with fruit resembling in shape and some other circumstances that which he already knows by the name of *plum,* but of a purple colour, he names this a *purple* plum; and in the same manner he denominates a third a yellow plum. Here plum is the generic term, and green, purple, and yellow, specific appellations. In thus acting, therefore, the savage makes a step towards a science, which, as such, is unknown to him; and, without intending it, performs one office of the Botanist.

But it is not till long after this period, till society has attained some regular form, and till men begin to perceive that a concurrence of similar circumstances is necessary for the reproduction of certain appearances, and that the operations of nature are not the effects of fortuitous causes,

that science really begins to dawn. It was in this state in Chaldea, when Botany, which is said by Botanical historians to have originated there, made its appearance as subservient to medicine. That the sufferings, as well as the wants of the human body should have given rise to the knowledge of the medicinal properties of vegetables is not surprising: for one of the unhappy but ordinary effects of the advancement of society is a violation of the laws of Nature, inasmuch as these regulate our appetites and tastes, the natural consequence of which is the production of diseases. To obviate these evils, remedies were to be sought for; and, either by accident, or by observing the effect of instinct on the lower animals, they were first obtained from the vegetable kingdom.

The knowledge of plants which the Chaldeans had gained for so important a purpose, was treasured up as a rich legacy, to be handed down from father to son; and in this manner the infant science was cherished till it passed into Egypt. With the Egyptians, however, and even with the Greeks, who received the science from Egypt, it did not make any great advances. Accustomed to rest too much upon genius and reflection, and careless of facts, the Grecian philosophers advanced the most absurd doctrines regarding vegetable life. They taught that plants possess a sensible and reasonable soul; have desires and

wishes; and are capable of experiencing pleasure and pain. Empedocles even, to whom, however, is due the merit of having first hinted at the sexes of plants, went so far as to assert that, after a time, plants change to animals, and then the sexual organs, which in the vegetable state are frequently united in one individual, become separated.

In Greece, for a long period, the knowledge of plants was altogether confined to the Asclepiades or priests of Æsculapius, who were the physicians of their time: and in the highest plenitude of the taste, elegance, and learning of the Grecian Commonwealth; even in that happy period, when the effulgence of Grecian genius burst forth in all its splendour, and shone till the time of Alexander the Macedonian, Botany had attained but a very limited extent, among the other sciences then cultivated. In the works of Theophrastus, who lived about three hundred years before CHRIST, and inherited the learning of his great masters, PLATO and ARISTOTLE, may be seen all that was known at that time regarding vegetables. His History of Plants, entitled, Περί φύτων ἱστορίας *, contains the description of only five hundred species, which were officinal, or used for the cure of diseases.

* Περί φύτων ἱστορίας, seu Historiæ Plantarum, lib. ix. cum Comment. J. C. SCALIGERI et J. BODÆI a Stapel. *Amsterdam*, 1644.

The Romans, that extraordinary people, who, for the space of seven hundred years that they were engaged in almost perpetual wars and commotions, spread by the force of the sword, the blessings of civilization over the barbarous part of the world; and who drew all their knowledge from the more refined nations over whom their arms had triumphed, began to study Botany, soon after their victory over Mithridates. They did not, however, add much to the discoveries of their instructors. The works of DIOSCORIDES, a native of Anagarba in Cilicia, who flourished under the tyranny of Nero, and wrote on the Materia Medica *, contain descriptions of scarcely more than six hundred plants; and the elder Pliny †, who flourished a short time (about sixty-four years) prior to the birth of Christ, after having collected all the information of his predecessors, has described one thousand plants only; but he acknowledged there were many more, which, however, as they had no names, and were of no use, he did not describe. The irruption of the Goths, and other northern nations upon the Roman empire, drove Botany, with the other sci-

* Περὶ ὕλης ἰατρικῆς, de Materia Medica, lib. vi. VON KOLLAR. *Vienna*, 1770.

† Pliny was a native of *Verona:* he fell the victim of his scientific ardour, in endeavouring to approach the crater of Vesuvius, during an eruption, in the 56th year of his age.

ences then known in Europe, for refuge into Asia. There, however, it obtained merely an asylum; few or no discoveries were made; and the works of Galen, Oribasius, Ætius, Ægineta, and other Asiatic writers, as well as those of Mesue, Serapius, Razis, Avicenna, and the other Arabians, contain little more than the names of the plants described by the primitive authors.

It is melancholy to look back upon the state of Europe during that period which has been justly denominated the dark age. A dismal gloom enveloped the whole of the civilized world: ignorance, superstition, and barbarism tyrannized over learning and genius; knowledge of any kind was to be acquired only by searching among the rubbish of the schools and monasteries; fabulous legends supplied the place of truth; and the deceptions of a crafty priesthood debased at the same time that they enslaved the minds of men. During this long and melancholy course of years, the few scattered writings that appeared on Natural History were the production of monks, and compiled from old authors: but even these were cloaked in an almost unintelligible jargon; and it was not till the middle of the sixteenth century, that the sun of science again burst this thick cloud, and shed its rays upon the north of Europe.

At this period Botany, which was exactly in the same state as the ancients left it, could not be

considered any thing more than a catalogue or list of the names of about one thousand plants: for, although the ancients were great observers, yet they did not make much use of their observations. They looked at Nature rather with the eye of the poet than of the philosopher; and, in giving the reins to imagination, were too powerfully charmed with her more striking beauty and sublimity, to descend to a calm and patient investigation of the causes of the effects which they observed. Thus, they knew that the farina of the male Palm was necessary to fecundate the female; but from this fact they drew no inference as to the difference of sex in plants: they grafted, but knew not the cause of the union of the graft with the stock: they had even observed the spontaneous movements of some plants, but did not endeavour to discover the reasons of the phenomena. Such was the state of the science at the revival of learning, when it made its first step towards improvement, in the representation of plants by wood cuts *; and this aid to the study of Botany was soon adopted by Brunfels, a physician, at Bern, who may justly be regarded as the restorer of the science in Europe †.

* An *Italian Flora*, which was printed at *Padua*, in 1485, is supposed to be the earliest book on Botany that was illustrated by plates.

† His work is entitled Historia Plantarum. The plates are not very accurate; but this is not much to be wondered at, when we reflect that he died in 1534.

To endeavour to display even an accurate sketch of the progress of the science, from his time to that of Linnæus, within the compass of a Lecture, would be vain; we shall notice, therefore, a few only of the more remarkable occurrences.

Near the close of the sixteenth century, CÆSALPINUS *, a Florentine, one of the professors of the University of Padua, made the first attempt at classification; for, previous to his time, plants had been described without any order, and the possibility of simplifying the study of the science by arranging them in classes, had not yet been conceived. JUNGIUS followed in the footsteps of Cæsalpinus, and by taking a clearer and more extensive view of his subject, the idea of those principles on which the Linnæan system is founded, suggested itself to him, and was developed in his writings: he died in 1657. JOHN RAY †, an Englishman, succeeded Jungius, whom he followed in many particulars, in preference to his cotemporary the great Tournefort, whose merits as a systematist were only exceeded by those of Linnæus. Ray was a man of laborious research. His work, entitled *Historia Plantarum*

* This celebrated naturalist, who was born at *Arezzo*, in 1519, threw great light upon the vegetable structure; and was the first of the moderns who hinted at the sexes of plants. He died in 1603.

† RAY, who was a native of *Essex*, was born in 1628, and died in 1705.

*generalis (London* 1693), contains all the Botanical learning of his time; and displays, in a striking degree, the unwearied assiduity and extensive reading of its author. The first time, however, that Botanists began to be really guided by the light of nature in their researches, was soon after the establishment of the Royal Society, towards the end of the seventeenth century; when Dr. Grew, in this country, and Malpighi on the continent, began their anatomical investigations. The acuteness, patience, and ardour of these celebrated men, in examining the structure of plants, remain yet unequalled, and their works are still standards on vegetable anatomy. Towards the end of the seventeenth century, Camerarius first proved the existence of sex in plants by observation and experiments; Geoffrey, and Vaillant *, a pupil of the great Tournefort †, confirmed, and added to his observations; but this important fact had few supporters till Linnæus made it the foundation of his system. We mentioned before, that Cæsalpinus

* Vaillant was born at *Vigny*, in 1669, and died at Paris in 1722.—His observations are contained in an Essay entitled, *Sermo de Structura Florum*. Lugd. Batav. 1718.

† Joseph Pitton de Tournefort was born at *Aix*, in Provence, in 1656. He travelled into Greece and Asia, at the expense of Louis XV.; and published a system of Botanical arrangement, founding the classes on the formation of the flower, while the orders were ascertained by the fruit. He died, in 1748, from an injury to his chest, occasioned by his being crushed by a carriage.

gave the first hint of this circumstance, but he did not pursue the idea; and the honour of starting this important physiological proposition has also been given to Sir Thomas Millington, who is said to have made the discovery in 1676. He never wrote any thing, however, on the subject; but merely communicated his ideas to Dr. Grew; and the uncertainty of the claim of originality on this account, detracts much from the celebrity, which such a discovery would have conferred on his name.

The improvements in Botanical science, that had at this time gradually taken place, were much forwarded by the inventions of printing and of engraving, which disseminating to a wide extent every new discovery, and displaying the figures of plants, in a correct and natural manner, attracted men of genius in every country to the study of the science. The advancement of navigation, and the increase of commerce, had also a considerable share in producing those beneficial effects: for by their means the plants of different climates were brought together; and the Botanical gardens of Europe enriched with the productions of every quarter of the globe. It may not be uninteresting to know, that the first Botanic garden was established at Padua, in 1533; and that it still exists, after the lapse of more than two centuries and a half, amidst the changes of revolutions and the overturn of

states, which, in that period, have astonished and convulsed Europe. At length the correct judgment, cultivated mind, unwearied assiduity, and sublime genius of Linnæus, gave to the whole science a new and more attractive aspect. It would form a pleasing episode, were it consistent with our plan, to enter minutely into the biography of this great naturalist*. The display of his transcendent abilities, like those of many other illustrious men, depended upon accident; and but for the kind offices of a physician of the name of Rothman, those of Linnæus would have been for ever suppressed, his father having felt so much disappointment with his earlier studies, that he conceived he was only fit for a tradesman, and destined him to be a shoemaker: but this benevolent physician persuaded him to allow his son to study medicine; and he himself became his preceptor. The poverty of Linnæus obliged him to struggle with great hardships in his earlier years†. His expenses in his Lapland tour, which, however, amounted to seven pounds ten shillings sterling only, were defrayed

* LINNÆUS was born at *Rashult*, a village in the province of *Smaland*, on the 3d of May, 1707. His father, Nicholas Linnæus, was pastor of the village; and his mother, Christina Broderson, the daughter of his father's predecessor in the church.

† When at Upsal he was glad to wear the cast-off clothes of his fellow-students; and his shoes were mended by himself with the bark of trees.

by the University of Upsal: and he was obliged to the lady who afterwards became his wife, for the money which enabled him to graduate at Leyden *. It was not till near the decline of his life, that his sovereign conferred on him those honours, which, if they could not add to his justly acquired fame, were enviable marks of the admiration which his talents procured for him in his own country. In 1735, two of his earlier publications, the *Systema Naturæ* and *Fundamenta Botanica,* appeared; and in 1737 he published five of his works, the *Critica Botanica, Genera Plantarum, Hortus Cliffortianus, Flora Lapponica,* and *Methodus Sexualis;* any one of which would have been sufficient to have conferred lasting celebrity on its author. As his fame extended, he was invited by the King of Spain to settle in his dominions, but declined the invitation; and was amply indemnified by the honours which his own sovereign conferred upon him. He was created a Baronet, and afterwards Archiator, or Dean of the College of Physicians; and a Knight of the Polar Star, some time before his death, which happened on the 8th of January, 1778. His system, the one which is now, with some modifications, generally adopted, is founded on truth and nature. It has been improved and

* This lady was *Elizabeth Moræus,* the daughter of a physician at Fahlun. She presented him with one hundred dollars, the savings of her pocket-money, to enable him to graduate.

occasionally altered since his death, as the extension of the science demanded; nor have the ignorant and the unqualified refrained from mutilating it by the most fanciful and useless variations: but from under the hands of both sets of reformers, the principles, and the groundwork, still remain, and are likely to do so, unchanged. His system is not, however, the only labour for which Linnæus deserves the applause of posterity: he made considerable researches in vegetable physiology, or the doctrine of the habits and economy of plants; and his endeavours to render Botany useful to medicine and to agriculture, are worthy of the highest praise.

It is to be lamented that biography has, hitherto, conveyed to us so few notices regarding the method of study pursued by those, whose characters as scientific men we respect and venerate; and our information, as to this particular of the life of Linnæus, is, indeed, extremely slender. We know little more, than that he very early began to seek nature in the fields, and to form a herbal; and that he read and studied "to the last glimpse of the midnight lamp." He fortunately, indeed, lived at a time when philosophy began to assume its most interesting character; when its votary, throwing aside the formal robe of pedantry, and quitting the maze of hypothesis, laboured to apply those principles which his industry, observation,

and ingenuity had accumulated, to procure the means of supplying the wants and increasing the comforts of his fellow-creatures; and of spreading over the paths of ordinary life those intellectual embellishments, the enjoyment of which forms the most distinguishing feature of difference between civilized man and the human savage. Such is certainly the ultimate aim of all science. How useless would have been the discoveries of astronomy, had they not been applied to the purposes of navigation! How vain would have proved the daring experiments of Franklin, in drawing lightning from the clouds, to prove its identity with the electrical fluid, if they had not pointed out the means of securing our dwellings from the effects of one of the most awful and dangerous of natural phenomena? What would have availed the labours of a Newton and a Boyle, a Black and a Cavendish, of Linnæus, Hunter, Volta, and Davy, did they not ultimately tend to benefit general society? Without such an object in view they would be but ingenious trifles, and a very straw in the balance, when weighed against the efforts of the meanest artizan.

Since the days of Linnæus, therefore, Botany, also, has displayed a more important aspect than it ever before assumed. The rage of making new systems and arrangements of plants has passed away, because these are no longer necessary: but

Botanists have arisen, and still live, who, besides illustrating and endeavouring to perfect systematic Botany, have advanced, in a great degree, the more useful parts of the science, by inquiring into the properties of plants, the phenomena of their functions and growth, and the effects they produce on the great system of nature. In this part of the science an extensive field is opened for the exercise of human ingenuity, the investigation of which is sufficient to employ, usefully, the longest life, and the highest powers of the understanding.

From the period of Linnæus the history of the science contains a long list of justly celebrated names. Among these we find HALLER, an anatomist, physician, botanist, poet, and politician, the friend at one time, but afterwards the rival of Linnæus; RUMPHIUS, who, although a physician, yet was appointed to the situations of chief magistrate and president of the mercantile association of Amboyna, the plants of which settlement he has described in his work, entitled, *Herbarium Amboinense;* ŒDER, who began the *Flora Danica,* the publication of which is still continued, under the patronage of the Danish government; SCHREBER, Professor at Erlangen and President of the Imperial Academy; JACQUIN, BERGIUS; PROFESSOR PALLAS; REINHOLD FORSTER, who sailed with Capt. Cook; THUNBERG, the author of the Flora Japonica, a work of unequalled merit; JUSSIEU, immortalized by his attempt to arrange plants in

a natural order; Sir Joseph Banks; Miller; Hedwig; Dryander; Gærtner; Sir J. E. Smith, President of the Linnæan Society; Willdenow; Professor Vahl; Humboldt, the South American traveller; Roxburgh; and many others, whose names are well known and not undeservedly celebrated.

Having finished the rapid sketch of the rise and progress of the science, which I proposed to exhibit to you, let us now pass on to the consideration of its utility as a branch of general knowledge. In reflecting upon this part of our subject, Medicine first presents itself to our attention, as deriving the greatest assistance from it. With the healing art, as we have already noticed, Botany originated; and, until the period of the renowned empiric Paracelsus, who introduced the use of chemical remedies, almost the whole resources of medicine were drawn from the vegetable kingdom. Although it can scarcely be denied that the use of mineral remedies has been, upon the whole, favourable to the advancement of the profession, by putting into the hands of its practitioners very powerful agents for altering and controlling, as it were, the powers of the animal system; yet it may be doubted whether mankind have not suffered, in some degree, by the change, inasmuch as the attention of the medical philosopher has been di-

verted almost altogether from the vegetable kingdom. Much certainly remains undiscovered of the virtues of plants in effecting the cure of diseases, and many excellent and very powerful salutary agents belong to that kingdom of nature.

As civilized men are not stationary beings, but are led by the thirst of gain, ambition, curiosity, or enterprise, to visit every part of the habitable surface of the globe, it is requisite that medical practitioners should be able to generalize, and, in searching for remedies to remove the morbid effects of changes of climate and other contingencies on the constitution, to know how to substitute the materials within their reach for those they have been accustomed to employ, but which they cannot in every situation obtain. The question may be reasonably asked, How is Botany to teach this knowledge? Let us examine how far we can satisfactorily answer it. Do we, in the first place, wish to ascertain which plants are poisonous or salutary? Botany teaches us that all those arranged in the family denominated *Cruciferæ*, in that of the *Rosaceæ*, and in those of the *Malvaceæ*, *Labiatæ*, and almost all the *Cerealia*, contain no poisonous species; that the *Mushroom* tribe, the *Solaneæ*, the *Apocyneæ*, the *Tithymalæ*, the *Ranunculaceæ*, and the *Papaveræ*, are almost all suspicious: and that the *Umbelliferæ*, the *Ari*, the *Polygonæ*, contain acrid and several deleterious

species. It also informs us, that some plants are acrid and poisonous when growing in water, which appears to be their natural element, although they are inert when they vegetate on dry land; and that some inert land plants become acrid when they accidentally spring up in water or in marshy places. Do we wish to discover the probable medicinal properties of the plants in any new situation, before we venture to try their effects upon the animal frame?—Botany informs us how to do so, by arranging the plants with which we are unacquainted, into their natural families. Thus we know that the *Solaneæ* are narcotic; the *Gentianæ* yield a bitter, and sometimes a purgative principle; the Laurel tribe a stimulant, which is in some instances highly deleterious; the *Corymbiferæ* are emmenagogue; the *Rubiaceæ*, to which Cinchona belongs, diuretic and tonic; the *Cruciferæ* antiscorbutic; and the *Malvaceæ* emollient. A medical Botanist, believing that a certain plant yields a peculiar medicinal principle, is led to examine whether the species of the same genus which are indigenous to the clime that he inhabits may not contain something similar, if not exactly the same; and thence discoveries valuable to his country, and sometimes to the human race, are effected. But this important method of generalizing can be practised only by the Botanist; for, to one ignorant of Botany, not only is the language foreign and unintelligible,

but the resemblances which characterize the various members of the same family, and which are perfectly obvious and striking to the Botanist, are overlooked and cannot be perceived by an ordinary observer. The advantages of a knowledge of Botany, also, and of the habits of plants, to the physician, are equally evident in the assistance they afford in the cultivation of a branch of the profession, which has lately been much and properly attended to; I refer to medical topography; a subject important to all, but absolutely requisite to the military medical practitioner. Suppose, for example, that an army is about to encamp in an enemy's country, and in a situation where circumstances may require that it should remain for a considerable time. The season of the year, and the kind of weather prevailing at the moment, may render it difficult for the medical staff to pronounce whether the place be healthy or otherwise; and the information afforded by experience is too late to prevent the impending evil, should it prove unhealthy. But the very plants which cover the soil clothe with a prophetic character the Botanical physician, and enable him to anticipate the danger which it is requisite to avoid. Yet how little has this branch of study been attended to in the education of professional men; who, before they presume to commence the performance of the duties expected of them, ought at least to be acquainted

with the nature and qualities of the implements they are about to employ in the cure of diseases.

A remark made to me by an old and respectable physician, the late Dr. Denman, explains in some degree the cause of this neglect: "I be-"lieve," said he, "that the practitioners of the "present period are sensible of the inadequacy "of the old method of bringing up young men "to the profession, and are therefore anxious to "send out those brought up under them better "instructed, and with a firmer foundation of prin-"ciples than was the case forty years ago: but "the ardour of youth to take an early, active "share in the bustle of life, places many obstacles "in the way of accomplishing their good inten-"tions." The justness of the observation is too obvious; and as medical men, after they have once entered upon the busy stage of life, cannot well retrace their steps, happy would it be for students were they to take advantage of the experience of their predecessors, all of whom, I will venture to assert, believe that much anxiety, much trouble, would have been saved to themselves, and much more pleasure and reputation gained in the exercise of their profession, had a few more years been spent in their education, and a few more collateral studies been attended to during that period. The practice of medicine is the study of a lifetime; it is entered upon the moment a man

begins to prescribe, and it must be unremittingly continued*; but little satisfaction can be derived from it, if the mind be not previously well stored with principles, and enlightened by a liberal education. By the force of natural genius and a good address, an ignorant physician may float for a while in honour's atmosphere; if fortunate, he may even be respected, and may attain wealth and reputation; but, when an unexpected difficulty occurs, his deficiencies appear, the bubble bursts, his reputation is dissipated, and he sinks neglected and despised. The properly educated physician, on the contrary, may rise slowly at first; but, like the sun, his strength increases as he rises; and, although he must naturally decline with gathering years, yet, when he sets, it is with equal dignity, only with a milder lustre. And surely, to use the language of a celebrated moralist, "to desire the "esteem of others for the sake of its effects, is not "only allowable, but in many cases our duty; "and to be totally indifferent to praise or censure "is so far from being a virtue, that it is a real "defect in character †." Botany is one of those collateral sciences, which is not only useful, but

* The following words of Linnæus, contained in a letter to Haller, should be impressed on the mind of every student: "Disco adhuc; ignoscas quod doctus, etiamnum non evaserim."

† Dr. Blair, Sermon VI. vol. ii.

adds grace to the medical character. Did I wish to select examples in support of this remark, I need only point to the works of *Prosper Alpinus, Sir Hans Sloane, Malpighi, Haller, Alston, Lewis,* and of our own contemporary, the indefatigable *Orfila.* A practitioner, indeed, unacquainted with Botany, may know the names of many plants and their uses; he may even gain a knowledge of the physiognomy of a few of them; but his ideas are obscure and confused; his ignorance may often be rendered conspicuous where he would most desire to conceal it; and it lays him open to the arts of the designing, and of those who would wish to expose him. Of the advantages which the profession has derived from the labours of Botanists, I need mention a very few only of many examples that might be adduced: the reintroduction of the Foxglove by Dr. Withering, as a remedy for dropsies, and the recent extension to this country of the Pyrola umbellata, and the Gum Acaroides. As many of the medicinal plants appear as common weeds, a medical man ought to be able to distinguish these when required; and, in the case of vegetable poisons, nothing will sink him more in the opinion of others, than his appearing ignorant of the plant which has occasioned the mischief; while nothing will raise him more in their esteem than his being able to point out its distinguishing characteristics, by which it may be known and

avoided in future. But a more important consideration still, to a reflecting mind, is, that by the degree of acquaintance which a practitioner has with plants that are poisonous to the animal economy, the life of a fellow-creature may be lost or saved. All poisonous plants do not produce the same effects, and these, consequently, require different modes of treatment; but if the plant which has caused the mischief cannot be ascertained, how is the remedy to be selected?

The utility of Botany to many of the other arts is not less obvious; and we are indebted to it for a variety of our comforts, both as to food and the luxuries of life. The grains so indispensable for our existence, the greater number of the fruits, and the most beautiful flowers, that enrich our orchards and ornament our gardens, are of foreign origin; and many of them have been brought to us by Botanists whose inquiries had led them to visit remote countries. The Horse Chestnut, for example, now so common in our plantations, was conveyed to Europe from the north of Asia, by Clusius, a Botanist, in the year 1550. The Kidney Bean, Phaseolus *vulgaris*, was brought from the East Indies: and the Nol-kol, the root of which affords a large supply of wholesome nutriment, has just been introduced from the same place. The Crown Imperial, Fritillaria *imperialis*, was transported from Constantinople; the Camellia,

from Japan; many of the Roses from China; the Nasturtium from South America; and the Pelargonium, or Geranium, as it is improperly called, from the coast of Caffreria. The Potatoe, the chief support of a great majority of our poor, was first described by Caspar Bauhin in 1590; and afterwards brought into this country, whence it was dispersed over Europe*. In our own times we have seen the West Indies enriched with the Bread-fruit by the scientific skill of Sir Joseph Banks; and every day new plants are brought home and naturalized to our climate, of great importance both in an economical and political point of view †. Even the arts may be benefited by a knowledge of Botany. Thus, many fine statues might have been preserved, had the fact been sooner

* It is very generally believed that this useful vegetable was brought from Virginia by Sir Walter Raleigh; and Willdenow states that, "in the year 1623, he distributed the first "which he brought from Virginia in Ireland." Doctor Smith Barton has pointed out the errors of this statement: in the first place, Sir Walter never was in Virginia; secondly, he was not living in 1623; having lost his head in October 1618; and, thirdly, it is by no means certain that the first exclusive depot of the Potatoe was Ireland.

† The number of plants now known and systematically arranged amounts to 44,000; although those known by the Greeks, Romans, and Arabians, did not exceed 1400; and in Caspar Bauhin's time, all that indefatigable Botanist could collect for his *Pinax Theatri Botanici*, a work of forty years' labour, did not exceed six thousand species.

known, that the black spots which appear upon them is a vegetable fungus, the Lichen *niger* of Linnæus. The dry rot in wood, also, is a fungus.

It is related that Mahomet Bey, King of Tunis, was dethroned by his subjects for having the reputation of possessing the philosopher's stone. He was restored by the Dey of Algiers, upon promising to communicate to him the secret. Mahomet sent a plough, with great pomp and ceremony, intimating that agriculture is the strength of a nation, and that the only philosopher's stone is a good crop, which may be easily converted into gold. I mention this anecdote, because it conveys an impressive idea of the importance of Agriculture; between which and Botany the connexion is so natural, and the advantages to be derived by the farmer from a knowledge of it so apparent, that the neglect of it as an essential part of his education is, indeed, wonderful. But so blind are men, often, to their true interests, that agriculture in this country has, till within a few years past, been regarded as an employment fit only for the most uninformed part of society. Following stupidly in the footsteps of his predecessors, and guided by a few rules, which had been handed down to him from the rudest ages, the agriculturist was ignorant that a knowledge of the theory of his operations was necessary for enabling him to overcome unexpected obstacles; to guard against

the uncertainty of seasons; and to multiply the means of supplying the wants of the community and enriching himself. These mistaken notions are now happily vanishing; and the utility of Chemistry and Botany is beginning to be felt and acknowledged by the farmer. From the more general study of the economy of vegetable life, how many improvements might be suggested in the cultivation of even the most common of our useful plants! How many of those which are still regarded as useless weeds, might be found to be of great importance if their properties were accurately investigated! And certainly the nature of soils would be better and more easily known by an acquaintance with the different kinds of plants which each variety of surface produces.

But, besides these objects of utility, to the advancement of which Botany unquestionably contributes, it is likely to render a still greater service to social life, by the cultivation of that branch of it which assigns to each tribe of plants its altitude, its limits, and its climate; and which the French designate by the term *Geographie Botanique*. By its aid nature may be in some degree subdued by art, the mountains of Europe may be girt by the Cinchona, the vine may cluster upon our rocks, and the high Palmetto and Coco wave on the sunward sides of our native vales.

These examples are sufficient to show the uti-

lity of Botany in advancing many of the more important arts; and the study of it is no less beneficial as a branch of general education. If the intellectual enjoyments of a well-informed mind be a valuable possession, whatever can augment these must be considered as of great importance. Many branches of knowledge have this effect; and, although they cannot be considered as directly advancing our interests or fortune in our intercourse with mankind, yet the possession of them affords a more permanent satisfaction than either wealth or honour can bestow*. Botany is one of

* If we apply these observations to the fair sex, we shall perhaps immediately hear of the danger of producing literary women, of having wives that would leave the management of their houses to pore over the page of the philosopher, and be solving a mathematical problem instead of making a custard. We shall be told that learned women are insupportable, and use their acquirements as tyrants do their authority, making them weapons of oppression rather than the instruments of happiness. But a female pedant and a woman with a well-informed mind and liberal education are two different beings; and I would answer remarks such as these in the words of one of the sex †, which I think are completely convincing. "The fragile nature of female friendships," says she, "and "the petty jealousies that break out at the ball-room, have "been, from time immemorial, the jest of mankind. Trifles "light as air will necessarily excite, not only the jealousy, but "the envy of those who think only of trifles. Give them "more employment for their thoughts; give them a nobler

† Mrs. Barbauld.

these; and the pleasure to be derived from the knowledge of it is not confined to any period of life, or any rank in society. In youth, when the affections are warm and the imagination is vivid; in more advanced life, when sober judgment assumes the reins; in the sunshine of fortune and the obscurity of poverty; it can be equally enjoyed. The opening buds of spring, the warm luxuriant blossoms of full-blown summer, the yellow bower of autumn, and the leafless, desolate groves of winter, equally afford a supply of mental amusement and gratification to the Botanist.

I have thought it necessary to state these examples of the usefulness of Botany and the pleasures to be derived from the study of it, in order to satisfy the demands of those who consider that nothing ought to be attended to which does not present some immediate object of profit or of uti-

"spirit of emulation; and we shall hear no more of these paltry "feuds: give them more useful and more interesting subjects "of conversation, and they become not only more agreeable, "but safer companions for each other." I would add, that men who exclaim against learned women, often allow the sex an excessive and unrestrained pursuit of pleasure; and think so meanly of their powers of mind, as to believe them fit only to be amused with the fictions of romance. But, if pleasure be essential for the happiness of woman, it can be obtained from the pursuit of science, that knowledge which is founded on truth and utility, provided an early taste for it be implanted in the mind.

lity. What is the use of Botany? What can you gain by it? are constant questions. We have already stated our opinion as to what may be gained by it; but I would further answer such inquirers by an anecdote told of the Greek philosopher Heraclitus. This philosopher was very poor, but much respected, and visited by individuals of the highest rank. One day, when certain persons came to consult him, they found him paring turnips for his supper, and warming himself in a kitchen: the meanness of the place occasioned them to stop; upon which the philosopher thus accosted them: "Enter," said he, "boldly, for "here, too, there are gods."

We have now to consider what mode of prosecuting the study of the science upon which we are about to enter is likely to be productive of the greatest benefit.

Botany, as we before observed, is that science which teaches the knowledge of vegetables, their structure, habits, and properties; and to distinguish different plants from each other; or, it comprehends *Phytology* and *Systematic Botany**.

* Vegetable physiology, indeed, cannot be separated from systematic Botany; for, to use the words of a French writer, M. Aubert du Petit-Thouars, "it is essentially the basis upon "which that science is raised; and the more this basis shall be "known, the more Botany, already so attractive in herself, "will see the number of her disciples increase."

Vegetables, like animals, are organized living bodies. To the superficial observer there appears no difficulty in distinguishing them from animals and fossils; but those who have examined the subject more minutely, find many obstacles to prevent them from drawing the exact line of distinction between the three kingdoms of Nature. Still, however, vegetables possess peculiarities of structure, habit, and functions, which characterize them; and these are found in every plant. As plants are living beings, so are they also perishable: death, as is the case in animals, may either proceed from innate causes, depending upon their organization, or be produced by external causes. It is obvious to our senses, that vegetables derive nourishment from the soil in which they are fixed, and in which they grow, and perfect seed capable of reproducing the species. The researches of philosophy have further informed us, that they possess irritability, by which the nutriment they imbibe is progressively moved through every part of their bodies, converted into various secretions, and assimilated into the substance itself of the plant; and that, like animals, they produce certain changes on the atmosphere, and can accommodate themselves to the vicissitudes of heat and cold. In the functions of generation, also, plants have many of the peculiarities of the most perfect animals. In stating, however, the close analogy between plants

and animals, we must always bear in memory that they have one important function less than animals—sensibility *. The losing sight of these circumstances, particularly the former, led the ingenious Darwin into a labyrinth of error; and has exposed his memory to the sarcasm of malevolent wit and the derision of ignorance. That part of our subject therefore, which refers to the economy of the vegetable system, should first engage the attention of the student. It constitutes Phytology, and comprehends the Anatomy and Physiology of plants; and is the most amusing, and certainly not the least instructive part of the science. The anatomy of plants is more difficult than that of animals, from the minuteness of their parts, the union of them, and the extreme difficulty of separating them without destroying their texture. If, however, it be more difficult, it is less disgusting, and the microscope very much facilitates our inquiries. Without it we can have no idea of the structure of plants, and consequently no correct notions of their functions can be obtained. In studying the Anatomy the Terminology is acquired, an acquaintance with which is absolutely necessary for securing a knowledge of systematic arrangement. By combining with these the study

* "Vegetabilia, sensatione licet destituantur, æque tamen ac "animalia vivere probat *ortus, nutritio, ætas, motus, propulsio,* "*morbus, mors, anatomia, organismus.*"—*Philos. Botanica,* §133.

of the Physiology, on which modern Chemistry has thrown the most brilliant light, the tediousness of acquiring the terms of art is diminished, and much interest excited in the pursuit. It is necessary to state that Botanical Terminology is that part of the science which has been less improved than any other, since the time of Linnæus. Some reform, similar to that which chemical nomenclature has undergone, is wanting, to remove the rubbish with which it is encumbered; for, although arbitrary terms are less objectionable in Botany, yet the terms employed should be clearly defined, and comprehensive. I would recommend, on this part of the subject, the perusal of Sir J. E. Smith's Introduction to Physiological and Systematic Botany; Rousseau's Letters on the Elements of Botany; Mr. Curtis' Lectures; Willdenow's Principles of Botany, which have been well translated; and, to those who read and understand French, the Traité d'Anatomie et de Physiologie Végétales, of Mirbel; but, above all, the Philosophia Botanica of Linnæus. Those who wish to investigate the subject more closely, will find great satisfaction in looking into the works of Grew and Malpighi; Du Hamel, Hedwig, De Saussure, Gærtner, and Spallanzani; and Mr. Keith's System of Physiological Botany. But I will forbear, at present, from loading your memories with the names of authors, and rather notice them as we proceed,

when the various subjects which each has particularly treated of come to be noticed.

By making ourselves acquainted with the structure and functions of vegetables, we are prepared to examine them as parts of a system; and thereby become acquainted, as it were, with each individual of this extensive kingdom of Nature.

The astonishing diversity of form and colour with which Nature has clothed the members of the vegetable kingdom, required that some mode should be devised for distinguishing the different kinds of plants. What is termed the natural method seems, at first sight, the most easy, and the best; and certainly, if it could be rendered perfect, it would undoubtedly be so; for, in many of the families of plants, such as the Grasses, Ferns, Lilies, Roses, &c. there is such a natural affinity between the different species of each class, and so marked a distinction of the classes, as not to be mistaken; but this is not the case throughout the vegetable kingdom; and, even in some of those natural classes which I have named, species are found which render it exceedingly difficult to know in which natural class they should be placed. Many Botanists, however, have endeavoured to produce systems of arrangement, according to these natural affinities; but hitherto they have not succeeded, not even excepting Jussieu, whose very learned and valuable work is far from an-

swering the purposes for which it was intended. Indeed, on examining the whole vegetable kingdom, the attempt to divide it into natural orders and families offers difficulties which, in our present state of knowledge, appear insurmountable. The artificial method of classification was therefore thought of; and that of Linnæus is the best and most perfect that has yet been contrived. I will not now even hint at the construction of this system; but merely observe, that, although it is an artificial system, yet that it is founded on the most correct observation of the phenomena of the vegetable kingdom; and plants are arranged by it under Genera and Species, as the individuals discover in the essential parts of the flower common properties and a natural affinity. This the young Botanist must study with the greatest care. Without a knowledge of it no one can be accounted a Botanist; and, by means of an acquaintance with it, the memory becomes capable of retaining a recollection of the characteristic features of all the plants, which already so greatly swell the vegetable catalogue; and the number of which is every day increasing. This, however, cannot be attained from the perusal of books; an appeal must be made to Nature, and plants examined in their growing state. In order to do this in a proper manner, as far as the plants of our own country are concerned, the Botanical

student must range the fields, and find the objects of his researches in their most perfect states, and in those places where the hand of Nature has planted them. For exotics he must have recourse to the Botanic Garden; and, although he cannot expect to procure the specimens in a state of perfection, yet he will obtain more information from examining them, such as they are, than can be acquired from the perusal of the best descriptions *, assisted by the best plates.

Such is the outline of the plan of study I would recommend; and which I shall endeavour to fill up by this course of Lectures. But I must observe, that no lectures can convey a complete knowledge of any Science. They are intended merely to assist the student in his inquiries, and, like a pioneer, to open a path, the intricacies of which must be afterwards prosecuted by himself. He must endeavour to woo Nature in her most secret recesses; but he may rest assured that she is not to be won without constant assiduity and attention; that she is a very coy mistress, and will not bestow her favours upon the indolent and the indifferent; while, on the contrary, on the attentive and the industrious, she lavishes her choicest treasures with an unlimited liberality.

* The best systematic works are, the Genera Plantarum of Linnæus; Persoon's Synopsis Plantarum; Withering's Botany; Smith's Flora Britannica; and Willdenow's edition of the Species Plantarum.

# LECTURE II.

## DEFINITION OF A PLANT—GENERAL VIEW OF THE VEGETABLE FUNCTIONS.

The division of all natural objects into three great classes is so simple and apparently so consistent with nature, that it must have originated at a very early period of society; and the more attentive observations of Philosophers, for a series of ages, although they have found unexpected difficulties in fixing the exact limit of these divisions, yet, have discovered nothing to prevent altogether their adoption. Philosophers, therefore, almost by common consent, have classed all natural productions according as they appear to belong to the animal, the vegetable, and the mineral or fossil kingdoms.

There is no difficulty in distinguishing a mineral from a vegetable; for, although some Lichens appear to the eye more like parts of the rock or the stone to which they are attached than distinct organized living bodies, yet, in nothing, except in the want of sensation, do the members of the vegetable and the fossil kingdoms agree.

To distinguish a vegetable from an animal does

not appear, at first sight, to be less easy. But he who investigates the subject more closely finds unlooked-for obstacles, arising from the unbroken chain of connexion which seems to unite these two classes of beings; and is forced to acknowledge the impossibility of fixing upon that link of it, which marks the termination of the animal, and the commencement of the vegetable state of existence. That a perfect animal can be easily distinguished from the more perfect productions of the vegetable creation is undoubtedly true; as no one could hesitate, for an instant, in which of the kingdoms of Nature to place a dog or a rose; but the difficulty arises when the strikingly characteristic functions of each kind of life are, as it were, confounded. Thus, not many years since, naturalists were undetermined whether to consider corals and corallines, polypi, and other zoophytes, as vegetable or animal beings. The difficulty of fixing upon the proper limits of these two kingdoms of Nature, and the circumstance of the members of both being living organized bodies, and thus differing decidedly from fossils, have induced the moderns to propose the division of natural objects into two classes only, INORGANIC and ORGANIC: the first comprehending all those bodies which submit to the general laws of chemical attraction and affinity and of mechanics; and which do not possess life, as, gases, fluids, earths,

salts, and metals; the second comprehending living beings, as animals and vegetables. The latter is the object of our inquiries; and, as it is of some importance to mark the point of distinction between animals and vegetables, we shall first examine the truth of those definitions of a plant which have been at different times delivered by Botanical Philosophers; and adopt that one which, in our opinion, is the least likely to mislead.

The first that we shall notice is that of Jungius, a Botanist who, as has been already stated (Lecture I.), lived about the middle of the seventeenth century, and who first hinted the principles on which the Linnæan classification is founded: "A plant," says he, "is a living but not a sentient "body, affixed to a certain spot or seat, whence it "can draw nourishment, grow, and finally propa"gate its species *." In this definition the want of sensation and of locomotion, or the power of changing place, are considered as the chief distinguishing characteristics of a plant; but we shall afterwards show that this definition is not to be adopted, inasmuch as some animals, if a *sensorium commune*, or a nervous system, is to be regarded as the medium of sensation, possess no sensibility; and some are immoveably fixed to one spot.

* "Planta est corpus vivens non sentiens, seu certo loco "aut certæ sedi affixum, unde nutriri, augeri, denique se pro"pagare potest."—*Jung. Isagog.* c. 1.

Keeping the same idea in view, Boërhaave, who flourished at the beginning of the following century, defines a plant thus: "A plant is an organic "body, fixed to some other body by some part of "itself, by which it imbibes the matter of nourish- "ment, of growth, and of life *." The same opinion was also entertained by Ludwig, a cotemporary of the great Linnæus, who says, "Natural bo- "dies, having always the same form, and endowed "with locomotion, are called animals; those "which have always the same form but are desti- "tute of locomotion, vegetables †." In all of these definitions the want of a locomotive power is chiefly insisted on as being the most peculiar distinguishing characteristic betwixt a vegetable and an animal: but, although we may allow that plants are destitute of locomotion, yet there are several genera of the molusca and testaceæ, corals, corallines, and some of the zoophyta, which incontestably belong to the animal kingdom, that are immoveably fixed to a single spot; either to the bottom of the sea, or to rocks, or to shells. The

* "Planta est corpus organicum, alteri cuidam corpori "cohærens per aliquam partem sui, per quam nutrimenti et "incrementi et vitæ materiam capit et trahit."—*Historia Plant.* 3.

† "Corpora naturalia eadem semper forma et loco-motivi- "tate prædita appellantur animalia; eadem semper forma, sed "loco-motivitate destituta, vegetabilia."—*Ludwig. Veget.* 3.

want of locomotion, therefore, cannot, with propriety, be regarded in a definition as a distinguishing characteristic of vegetables.

I have already stated that Jungius mentions the want of sensation as distinguishing plants; an opinion which Linnæus also held: "Lapides crescunt," says he, "vegetabilia crescunt et vivunt, animalia "crescunt, vivunt, et sentiunt*." "Stones grow, "vegetables grow and live, animals grow and live "and feel." Although this opinion has been disputed by several philosophers, and Sir J. E. Smith, in his Introduction to physiological and systematical Botany, puts the idea of vegetables being sentient beings as an admissible supposition, yet there is more reason for thinking that they are not endowed with this principle, which seems to be the peculiar attribute of animal life. We can scarcely form any idea of an animal devoid of sensation; but the spontaneous movements which are observed in some plants, and on which the opinion of their sentient power is founded, may, perhaps, be accounted for, independent of sensation. Sir J. E. Smith, in support of his opinion, says, "Such "a supposition accords with all the best ideas we "can form of the divine Creator; nor could the "consequent uneasiness," adds he, "which plants "must suffer, no doubt in a very low degree like-

* Phil. Bot. 5.

"wise, from the depredations of animals, bear "any comparison with their enjoyment on the "whole." Before perusing this passage of Sir J. E. Smith's work, we thought this fanciful idea had sunk into the grave with Dr. Darwin; and we must acknowledge that our inflexible imaginations have never yet been able so far to overcome the suggestions of cooler judgment, as to lead us to suppose that the general sum of enjoyment would be increased by such a circumstance. It must, however, be allowed, that the spontaneous movements of some plants which we shall hereafter notice, appear at first sight to be the effect not of sensation only, but even of volition; and, although the possession of that faculty by vegetables cannot be proved, yet neither can it be completely disproved. The experiments of M. Humboldt with the galvanic pile upon those plants which are particularly irritable and are generally regarded as possessing sensibility, tend, perhaps more strongly than any observations that have been made on the spontaneous movements of plants, to settle this question. He did not succeed in rendering any of them susceptible of the galvanic influence. Until, therefore, further observations be made, tending to confirm the opinion that vegetables are endowed with sensation, or to disprove it completely, the definition which mentions the want of it, as the

distinguishing characteristic of plants, cannot be regarded as correct.

M. Mirbel, in a late work, entitled, *Traité d'Anatomie et de Physiologie Végétales*, has given an opinion, which Sir J. E. Smith considers as conclusive on this subject. He observes, "that plants "have the power of deriving nourishment from in-"organic matter, which is not the case with ani-"mals, who feed on animals and vegetables, and "sometimes on both; but are never nourished on "earths, salts, and airs. So that it should seem "to be the office of vegetable life alone to trans-"form dead matter into organized living bodies*." This remark is, certainly, exceedingly ingenious and plausible; but it contains an assumption which cannot be admitted to the extent required; for, if by inorganic matter is to be understood simple earths and salts, which do not form parts of decaying organized bodies, the observation is not just; nor can we allow that airs are taken in *as food* by plants. What soil can be found com-

* "C'est la faculté qu'ont les plantes de se nourrir de sub-"stances inorganiques, faculté qui ne paroît pas exister dans "les animaux: ils devorent des substances animales ou végé-"tales, et quelquefois les unes et les autres; mais jamais, ce "me semble, ils ne se nourissent de terres, de sels, d'air et de "gaz. Ainsi, les végétaux doivent, pour condition première "de leur existence, transformer la matière brute en matière "organisée et vivante."—Tome i. p. 19.

posed of simple earths devoid of animal and vegetable matter in which plants will grow? And it is well known that the presence of a large quantity of salts, even of those kinds which, in small quantities, promote vegetation, is more likely to kill plants than to serve as nourishment to them. A plant, it is true, may be reared in pure water, or in pure powdered flints moistened with water; but in this case the water is the support of the vegetable; and we know that many animals, the Infusoria, for instance, are nourished and supported apparently in water alone. As this fluid is the universal solvent, whatever it contains in solution may be taken up by the vegetable vessels; and the experiments of Sir Humphrey Davy have proved that even distilled water may contain both saline and metallic impregnations: hence we can conceive from what source the alkalies, salts, metallic oxides, and earths, even silex, which are found in vegetables, have been derived; but that these are directly taken in as nourishment by plants is not more likely, than that lime, which forms so large a portion of the animal structure, is, in its uncombined state, the food of animals *.

* It is rather surprising that Sir Humphrey Davy, in his late work on the Principles of Agriculture, adopts implicitly the opinion of Mirbel, that saline substances form part of the real food of plants; particularly as he adds, "and supply that "kind of matter which is analogous to bone in animals." Now

Salts serve to stimulate plants, and, by exciting the action of their irritable fibres, promote their health and growth; part of them are taken up along with the soluble vegetable matter contained in the soil, and disposed of in the economy of the plant, either in the simple state in which they were absorbed, or forming new compounds, generally neutral salts; and this is regulated by the peculiar nature of the plant, independent of any properties of the soil in which it grows. The same effect is produced on animals, by the saline matters taken into their stomachs along with their food. Some of the lower animals, as earth-worms and other species of the vermes, feed on vegetable and animal matters which have undergone decomposition, and returned to that state in which they are generally found in soils. Vegetables, therefore, in common with these animals, although certainly in a more striking manner, have the power of recombining and assimilating into organized bodies those materials which the loss of vitality had allowed to be separated by the chemical affinities of their constituents, or to be decomposed, but are incapable of transforming matter, which has never formed any part of organized bodies, into their own living

we may ask the learned Professor, if phosphate of lime forms a direct part of the food of animals, in order that bone be produced.

organized substance. If these observations be just, the remark of M. Mirbel cannot serve as the means of distinguishing animals from vegetables; or of forming a correct definition of a plant.

The most satisfactory opinion I have met with on this subject is that supported by Dr. Alston, who was Professor of Botany at Edinburgh about fifty years since, and who appears to have received the idea from Boërhaave. He makes the distinguishing characteristic of vegetables to consist in the want of an internal stomach, animals being nourished by their internal, and plants by their external surface. It is extremely difficult to find any thing like an exception to this opinion; nor do we think that the proofs of it fail with respect even to the Polypus, whose construction is so simple, that it may be turned inside out like a glove, without disturbing its ordinary functions*. Polypi seize insects that come near them with feelers, which they spread out in the water, and convey them by this means to their mouths; and, as their internal cavity may be regarded as one entire stomach, the food is passed rapidly through

* It may not, perhaps, be unnecessary to observe, that a Polypus is an aquatic animal, resembling in form the finger of a glove, and, in structure, appearing to be made of particles set in a gluey substance. Like those plants which can be slipped, a Polypus may be cut into any number of pieces, and each divided portion become a new Polypus, a distinct animal.

every part of the animal, even to the extremities of the feelers, which are also hollow. It is thus bruised; the soluble parts are absorbed, and the remainder is thrown out by the mouth, which is also the anus of the Polypus. If a Polypus be turned inside out, that which was the external surface becomes now the stomach, and performs the functions of it, but still the food is taken within the animal; it is also taken at intervals only, and must remain within the animal some time to undergo the process of digestion, before any part of it can be absorbed by the lacteals and carried into the circulation: a Polypus, therefore, cannot be said to be nourished in the same manner as vegetables are, which is by continued absorption by the external surface.

If, as I suppose, no exception can be found to this remark, the characteristic which it points out as distinguishing animals and vegetables is very striking, and may properly form the leading feature in the definition of a vegetable: "A "plant," I would therefore say, "is a living or"ganized body, which requires food and air for "its support, grows, propagates its species, and "dies: and differs from animals, in being nourish"ed by continued absorption by its external sur"face." An objection to this definition has been anticipated by Mirbel, in combating the opinion of Aristotle and of Boërhaave, that plants are

*animals turned outside in.* "Il est naturel," says he, "de soupçonner que tout vestige de canal intestinal finit par disparaître dans les animaux infusoires *." But this is a mere conjecture; and there is no good reason for supposing that these animals have not an intestinal canal, although the smallness and transparency of their bodies prevent us from detecting it, even with the aid of glasses †.

Having endeavoured to give you a determinate idea of a vegetable, let us now take a general view of those functions which plants possess in common with other organized bodies, that is, with animals.

When a plant is examined with care, its structure is found, in many respects, to correspond with that of the animal body. It is composed of solid and fluid parts; the former comprehending fibres, which are endowed with elasticity and contractility, and vessels in which the fluids move. The most perfect vegetables, however, differ from animals in structure, in having no stomach, heart, brain, nor nerves; but all these organs are not

* Elémens de Physiologie végétale, &c. t. i. p. 11.

† For practical purposes, as Sir E. J. Smith observes, it is sufficient for the student to know that he may always decide whether "he has found a plant or one of the lower orders of "animals, by the simple experiment of burning:" the odour of burning animal matter being so essentially different from that of vegetable substances, as not to admit of being mistaken.

found in every animal; for many of the lower classes of animated bodies want one or more of them. As is the case in animals, the organs with which plants are furnished are always of the same structure in every individual of the same species, when in a natural and healthy state: and these organs are also susceptible of the same impressions from external agents, the circumstances being in every respect equal, in every individual of the same species. Thus any number of seeds of the same kind of Lily will produce Lilies all resembling each other in form and structure; the same number of parts will be evolved, and the unfolding of them take place in the same manner. The differences of soil, of situation, and of culture may occasion varieties in colour and other unimportant particulars, but the specific characters remain invariable. These facts are sufficient to prove that plants are endowed with life, or possess the same principle by which the existence of the organic structure, the growth, and the propagation of the species in animals are supported: but let us examine a little more closely those functions of vegetables which prove their vitality. Although vitality cannot properly be defined, yet we know it, when it is present in any object, by its effects, which are never displayed by unorganized matter; and therefore we are accustomed to define it by saying, it is "that property of matter connected

"with organization, which animals and plants "possess in common, of continuing life." Both animals and vegetables communicate it to their offspring. By viviparous animals it is communicated to the fœtus long before its expulsion from the uterus; by the oviparous, to the punctum saliens, which is afterwards the chick, before the egg receives its shell; and by vegetables, to the embryo contained in the seed, long before this has obtained perfection in point of size, and is separated from the plant. In these instances the functions of the new beings either immediately commence, as is the case in the fœtuses of viviparous animals; or they do not commence till the necessary agents are present for evolving the proper organs, as yet unformed or imperfect, as happens in eggs and in seeds: but, in both cases, it continues for a definite time only, and is then lost. During its continuance both animals and plants preserve their organization, and resist those chemical attractions or affinities which subsist between the different component parts of their bodies; and which, immediately when life ceases, act; and, by dissolving the old combinations, produce new ones, by the processes of putrefaction and fermentation, and render back their elements to the inorganic kingdom. We do not mean, however, to assert that organized bodies do not admit of chemical combinations, during life; as it cannot be denied that more complicated and diversi-

fied combinations are the direct result of the living principle, than can be produced by the simple power of affinity when it operates on dead matter. The particular functions of vegetables that depend on vitality are the *germination* of seeds, the *nourishment* and *growth* of the vegetating plant, its *absorption*, *perspiration*, and *respiration*, *adaptation to climate*, and *resistance of cold* during winter.

The seeds of plants, like the eggs of animals, being endowed with vitality, many of them may be kept for a very considerable time, even for a century of years; and yet, when they are placed under favourable circumstances, at a proper season, and in a situation where they can receive a sufficient supply of air, heat, and moisture, immediately begin to germinate and grow. If any thing tend to destroy this principle in the seed, instead of germinating, when placed in a situation favourable for germination, it rots; for, although the vitality which seeds thus possess does not depend on any external circumstances, yet, it may be destroyed by external causes. The time which it may remain latent is not the same in all seeds: some will not germinate unless they be put into the ground almost immediately after they be gathered; whereas leguminous seeds may be kept for ages, and yet preserve their vegetative power. The vitality of some seeds is indeed so permanent, that it pre-

serves them for an indefinite period of time, when under certain circumstances; as when some of the mucous-coated seeds, mustard or linseed, for example, have been accidentally buried at a considerable depth, and are again, after many years, thrown upon or near the surface of the ground. In this case, these seeds readily germinate, and become as vigorous plants as if they had been the produce of the foregoing year. It is owing to this circumstance, that often, when forests are cleared of the overshadowing trees, which had long prevented the vegetation of any seeds in the ground below them; or when buildings are razed, and the earth at their foundations turned up, plants suddenly appear, different from any in the immediate neighbourhood, and even unknown by the oldest inhabitants of the spot. If a seed, however, be once exposed to the action of heat, air, and moisture, in a situation adapted for its growth, it germinates, and its vegetation cannot then be stopped without destroying its vitality, and the seed of course rots; the continued application of the same agents, which first called into action its powers of life, being absolutely necessary for its future existence.

After the parts of a plant have been unfolded from the seed, its functions depend altogether on the vital principle with which it is endowed. It selects from the soil its nourishment, digests and assimilates it into its proper substance, and depo-

sits in its body those secretions which render it useful to mankind for economical and medicinal purposes. The simple absorption of fluids by the roots of plants might, perhaps, be explained on mechanical principles; but the circulation, or, rather, progressive motion, of the sap, can only be accounted for on the supposition that plants are living beings. Various theories have been offered to account for the ascent of the sap in plants; but this is not the moment for criticising these different opinions; it is only necessary to observe, that the sap continues to rise during the life of the plant, and ceases when it dies; and that it obviously does not depend on capillary attraction, or any mechanical impetus independent of vitality. If a plant in a flower-pot be kept for some time perfectly dry, till vitality ceases, no supply of water can again be taken up by its vessels, however favourable the temperature may be; for, in this case, the plant having been deprived of one essential agent, its vessels no longer act, and it dies. Did the ascent of the sap, however, depend on any other circumstance than the living action of the vessels (which, I trust, we shall afterwards be able to prove is not the case), it would only be necessary, in order to restore any decayed plant, to supply it with moisture in a proper temperature. Dead plants imbibe fluids, it is true, but they are not nourished by them; and the moisture

only serves to hasten the process of decomposition. When a plant has attained the natural term of its life and dies, or when its death is occasioned by lightning or any other accident, the absorbing power of the roots and leaves is lost; and the sap, which is contained in the vessels, is evaporated and dissipated; which would not be the case did these functions not depend on vitality.

To the living powers of vegetables we must also revert to account for the changes of the sap into the solid components, and the peculiar juices of the plant. No mechanical principles can produce these effects; they are opposed to the chemical affinities which exist between the materials composing the substance of the plant: nor can they result from any cause, except from that principle which, whilst it is present, gives life and motion to every being that is endowed with it; and, on being withdrawn, leaves the substance to the control of those laws that regulate the combinations of dead, inert, unorganized matter. It was the opinion of Linnæus and of many others, that, although the greatest variety of plants may grow at one time in the same field, yet that each of them selects and takes up from the soil those particles of it only which are adapted to the peculiar nature of their secretions; or that the soil contained ready-formed all that is found in plants. But there is no need of this supposition to explain the great variety of secretions of plants reared

in the same soil, if we admit that vegetables are living beings. Is it more wonderful that plants should elaborate the same nutriment into poisons and wholesome food, than that venom is secreted and lodged under the fangs of some species of serpents, whilst nothing of the kind is possessed by other reptiles that live on the same kind of food? In order to disprove that no such selection takes place, it is only necessary to rear any number of different plants in water alone: each plant, in growing, will assume the nature and possess the qualities of the species to which it belongs, whether that be poisonous or salutary: a proof that the qualities of the secretions of plants, like those of animals, are not dependent upon peculiarities of soil, but on the action of the vital principle.

Although every vegetable is a living being, yet all plants do not enjoy an equal share of vitality, nor are they all equally tenacious of life. Some plants die almost immediately, if they be deprived of moisture; whereas others, particularly some of the mosses, may be completely dried, and preserved in this state for a considerable time, even for years, and yet retain their vitality; so that the application of moisture will again make them resume their verdure and grow.

On the presence of the principle of vitality depends the power of reproducing parts that are destroyed. Thus, if a tree be cut down, and the

root left in the earth, it will again shoot forth new stems, branches, and leaves; and if the bark of a plant be partially cut away, it will be reproduced. This power, however, is not possessed by every plant, nor is reproduction observed to take place in every part of any plant. All those plants which may be regarded as compound beings (as trees, for instance, each bud of which seems to possess a distinct life), may have parts cut from them, which, if stuck into the ground under favourable circumstances, will throw out roots and grow, and each piece become an entire plant, similar to that from which it was cut. In some plants, even the leaves possess such a degree of distinct vitality, that any portion of a leaf, provided it contain part of the margin, when stuck into the ground, throws out radicles and becomes an entire and perfect plant, resembling that from which it was taken. The Bryophyllum *calycinum* is an example of this fact. But those which are considered as simple plants cannot be much mutilated without suffering. If the Cabbage, or head of a Palm, for example, be cut off, the plant soon dies; or if a Fir, or other resinous plant, be much pruned or cut down, no new shoots are produced; and if a leaf of any plant be once mutilated, it never again recovers that portion which it has lost. In this respect plants do not differ from animals. If a Polypus, and some kind of worms, be cut in

pieces, each part, as happens with the slips or cuttings of plants, becomes a perfect animal; and if part of a bone, or of a muscle, be taken away, it is reproduced by the vital powers of the animal; but the cutis, like the leaves of plants, when once destroyed, is never again restored.

Plants absorb and transpire watery fluids by their surface. If a plant, or part of one, as the branch of a tree, be placed in a humid air, as long as either of them lives, it will absorb the moisture from the air by its surface, and augment in weight. On the contrary, in a dry air of an increased temperature, it transpires fluid in the form of invisible vapour, in the same manner as animals part with what is termed their insensible perspiration. The intention of this function of plants is evidently to throw off the superabundant water, which is necessary for keeping the nutriment absorbed by the roots in a state of extreme solution; but which is no longer useful when the sap is about to be exposed to the action of the air in the leaf, and returned for the purposes of secretion and assimilation. The powers of absorption of the roots, therefore, must be regulated by the quantity of perspiration thrown off by the leaves and surface of the stems and branches; and Dr. Hales found by experiment that the quantity of transpired fluid was rather more than equal to the weight of the water imbibed by the roots. Plants, however, which

have thick succulent leaves, as the Aloes, and are natives of a warm climate, and dry arid soil, perspire very little, but absorb powerfully by the whole surface of the leaves. That these functions depend on vitality is evident, for both cease when the plant dies.

Another function of vegetables depending on the property we are treating of, is that which has been termed their respiration. Air is as essential for the existence of plants as of animals; and, whether we believe, with many philosophers, that they restore the pure part of atmospheric air that has been consumed by the breathing of animals, or join in the opinion of others, who believe that they produce the same changes on it, to a certain extent, as animals do, we know that it is during the life of the plants only that any such effect is produced. As the leaves are the principal organs by which this function is performed, it is most vigorous during the summer, while plants are clothed in the full luxuriance of foliage; and it is very much diminished when the leaves drop in autumn, almost ceasing in the state of torpidity of the plant in winter. Still, however, as the vitality of the vegetable then perpetuates its existence until the return of spring; the bare stem, and the branches, continue to operate the ordinary change on the surrounding air, although in a very small degree; but when the leaves decay, and the plant dies,

then, as is the case with animals, no further change on the atmosphere is produced than is occasioned by the process of decomposition.

Connected with this function of plants, and depending on the same cause, is that power which they possess in common with animals, of resisting to a certain degree the alternations of temperature of the atmosphere. Every animal and every vegetable has a peculiar innate temperature, independent of that of the surrounding air. The power of the animal body in preserving this degree in very low temperatures is truly astonishing; nor is its power less in resisting the effects of great heat. Dr. Fordyce, who was the first person that accurately remarked this last property of animal life in the human body, made several experiments in heated rooms, assisted by Dr. Blagden, Sir Joseph Banks, and some other gentlemen. In these the rooms were heated to a degree far exceeding any that can possibly take place in the natural atmosphere in any climate; and as a clear proof that it was the living principle alone which enabled them to resist such extraordinary degrees of temperature; in one of the experiments, a beef-steak, placed in the heated room with the persons trying the experiment, was roasted in forty-seven minutes. The power possessed by living vegetables of resisting the changes of temperature of the external air, cannot be supposed to be so great as that of ani-

mals. It is sufficient, however, to protect them from the effects of frosts, that would otherwise freeze the sap contained in the vessels of many of them, and destroy their organization: for, we find that plants live during frosts which freeze the deepest lakes; and dry up the moisture of every substance not endowed with vitality. It is nevertheless true, that some plants may be even frozen during winter, and yet be so tenacious of life as to revive in the spring; but this extraordinary circumstance is not peculiar to vegetable beings, as a caterpillar, for instance, may be frozen and yet live, after being thawed. The tender shoots that contain much moisture, and sickly branches, are however destroyed by severe frost: for the vitality in the latter case is not sufficient to preserve the innate heat; and in the former its power is not great enough to prevent the freezing of the superabundant moisture contained in the substance of the shoot; and as all fluids expand in the act of freezing, this effect tears asunder and destroys the delicate vegetable vessels. Nor can tender and sickly animals resist severe frost more than vegetables, but are immediately frost-bitten. When this happens, the part mortifies; and, although the vigour of the general habit be supported, yet, the frost-bitten part can never again be restored to its former state, but is separated as a dead slough from the neighbouring sound parts. The same effect is produced in a

plant; for, if the newly evolved leaves of a tree be attacked by severe frost, they also mortify, and drop from the sound twig. Vegetables resist heat also; for, a vine which is nailed on a wall will feel cool, when the wall can scarcely be touched on account of its heat: and fruits hanging in the sun remain cool, when a glass full of water placed in the same situation is quickly heated *. Mr. John Hunter found, by experiment, that while the thermometer stood under 56° in the open air, the temperature of plants, tried by placing the bulb of the instrument within them, was always above that degree, but under it when the weather was warm. Plants are, however, very susceptible of the impressions of heat; and feel its effects, as an agent acting on their vital energy, even partially; so that one part of a plant may be leafless, and in a state of inaction or torpidity, whilst another part is clothed with foliage. If some of the branches of a vine, for example, which is growing on the outside of a hothouse, be taken into the house, these will be covered with leaves very early in spring, whilst those that are exposed to the weather remain naked, and in the same state as other plants, growing in the open air, in that season.

* Mr. Forster, who sailed with Captain Cook, found the ground near a volcano, in the island of Tanna, so hot as to raise Fahrenheit's thermometer to 210°; and, at the same time, this spot was covered with flowers.

Vegetables require different degrees of temperature for the preservation of their vitality. The plant that flourishes under the ardent beams of a tropical sun, would quickly perish if exposed to the keen air of a northern latitude; while the Norwegian Fir, which raises its luxuriant head green amidst the waste of Arctic snows, would sicken, drop its leaves, and stand a lifeless trunk, if removed to the torrid zone. But living vegetables, as well as animals, gradually accommodate themselves to change of climate; although they retain their old habits for some time after their removal, and by slow degrees only are naturalized to new situations. Thus a fruit-tree, for instance, which has been reared in a hothouse, and afterwards planted in the open air, will, in the following season, expand its buds at the same time that it used to do, and so expose them to inevitable destruction; but after a few seasons, the natural habit of its species will overcome the acquired one of the individual, and the buds will remain shut up till the genial warmth of the returning sun, in spring, swells and expands them into leaves*. This power of plants, which naturalizes them to different climates, has enabled human in-

* Rice, which is a native of the torrid zone, has gradually travelled to Germany, where it is now cultivated; but Rice brought direct from the south of Italy will not vegetate in Germany.

dustry and ingenuity to diffuse more generally the productions of every quarter of the globe over its surface; for, had this not been the case, the plants of every climate must have always remained the same as they were at the creation of the world.

As the vital energy of vegetables is supported by the application of external agents, particularly heat, the abstraction of these in part must necessarily diminish the activity of the vegetable functions. This is the case in winter, during which season, plants, like some animals, remain in a torpid state; and, although they still live, yet the powers of vegetation are at a stand; and even in those that retain their foliage and verdure, no visible increase of their parts takes place. That their preservation during this period depends on an inherent living principle is obvious; for, when the severity of the season is sufficient to overcome its preservative power, no renewal of their active functions takes place at its termination: but, in general, as soon as the animal creation begins to feel the warmth of spring, the buds of trees swell, and protrude their leaves, and the plant rapidly advances in growth; with the increasing warmth of the summer sun the flowers are expanded, and the fruit arrives at perfection; till, as it declines in autumn, the leaves fall, and the state of torpidity is again resumed with the cold of winter.

Thus I have endeavoured to prove that vege-

tables, in common with animals, possess vital energy, which distinguishes them from inert matter, and displays itself by its effects. If we wish to extend the inquiry beyond the examination of these effects, and demand what *vitality* is? we are forced to pause, and acknowledge the inefficacy of human means to unveil those mysteries which the Author of nature chooses to conceal. We know that vitality is attached to organization; but it does not depend on structure: it is not caloric, the cause of heat, although with this agent it has the closest possible connexion: nor is it chemical affinity, for it resists in organized bodies those combinations which affinity produces among their components when vitality ceases. The flights of imagination fail us in forming any conjectures as to its nature; we search in vain for a solution of the question in the schools of Philosophy; reason avails us nothing; and we are forced to contemplate its effects in silent admiration, and to regard it as an impulse of the Divinity, breathed upon the organized part of the creation, astonishing and incomprehensible.

Another principle which vegetables possess in common with animals, and which depends on life, is irritability, or the susceptibility of being acted on by external stimulants, so as to produce a change in the parts, or the relative situation of the parts of the body, which, without the impression thus communicated, would not have taken place. Those

agents which are considered as natural stimulants to the animal body, as heat, light, air, and food, act also on the irritability of the vegetable; and their moderate application is absolutely necessary for the preservation of the life and health of a plant. When they are withdrawn the irritability accumulates, and the plant languishes; when they are applied in excess the vital powers are exhausted, and the plant also languishes; and if they be withdrawn, and then again applied suddenly, and in too great quantity, the plant dies, exactly in the same manner as an animal who is killed by indulging in a full meal after having been nearly starved.

To bring forward examples in proof of the existence of this principle in plants, in this stage of our inquiries, would be anticipating our future observations, nor could they be fully understood without a knowledge of the structure of the different organs in which it is more peculiarly displayed; we shall, therefore, only observe generally, that to it must be referred all the motions of plants, both general and partial; except such as depend upon the agitation of the air, or winds, and other mechanical causes, and which, like exercise to an animal, are absolutely necessary for the preservation of the health and vigour of the vegetable. I shall only now observe, that among the motions depending on irritability are those observed in some

leaves and flowers when touched; the turning of leaves to the light; the opening and closing of flowers at a certain hour of the day, or, as it has been termed, vigiliæ florum; and the sleep of plants *; each of which we shall minutely investigate in its proper place.

Plants, like animals, are destined to perform their functions for a limited period only; some live for one season, others twice that period: the Apple-tree flourishes through a century; and the Cedar is supposed to brave the tempests of a thousand years: but the hand of Time sooner or later presses upon all of them; and without the aid of external injury, their vegetative powers cease; and, sharing the fate of all organized beings, they submit to decomposition, and crumble into their primeval elements.

* Darwin (*Phytologia*, sect. viii. 4) ascribes these circumstances to volition; an opinion which I shall have an opportunity of combating in another place.

# LECTURE III.

## GENERAL COMPONENTS OF THE VEGETABLE STRUCTURE.

If any number of plants of the most diversified forms and structure, be individually cut, or divided or torn asunder, each and all of them will be found to consist of solid and fluid materials. A plant may therefore, as far as structure is concerned, be represented as a congeries of solids and fluids. Whilst, however, regarding it in this point of view, we must always bear in mind that both constituents are under the influence of the living principle; that the fluid parts, often differing widely in chemical properties, are not only retained within certain channels, and kept from mixing with each other; but are moved progressively by a specific action of the solids through the whole body of the plant; and altered in their characters so completely, that the secretions which result have no affinity whatever to the fluids imbibed from the soil and the atmosphere from which they are formed; and that, as in the living animal body, waste and repair are constantly going on in the vegetable system.

Under the solids are comprehended, i. The general solid components of the vegetable organization; viz. the *membranous*, the *cellular*, the *vascular* and the *glandular textures*, the *ligneous fibre*, and the *epidermis*: ii. The organs necessary for the preservation of the individual;—the *root*, the *trunk*, the *branch* and the *leaf* with their *fulcra* or *appendages*: iii. The organs requisite for the reproduction of the individual;—the *flower* and the *fruit* with their appendages: and, iv. Organs which hold a kind of dubious character, being in a certain degree both conservative and reproductive;—*bulbs*, *gems*, and *gongyli*.

Under the fluids are comprehended the *sap* and the *proper juice*; both of which may be regarded as general components.

Let us endeavour to acquire an accurate idea of each of these parts, without adhering strictly to the order in which they have been enumerated.

### i. GENERAL SOLID COMPONENTS.

The first of these, the *Membranous texture*, is an exquisitely thin, transparent, colourless, film-like membrane or pellicle, which is found in every individual of the vegetable kingdom. Du Hamel, and some other authors, have asserted that it is composed of organic fibres, arranged parallel to each other, and united by a glutinous substance; but, as Mirbel has justly remarked, " this is one

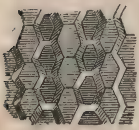
of those opinions by which the mind is amused, when research is fruitless." Indeed, the nicest microscopical examinations have not thrown any light on its structure; and we may safely aver that no appearances of organization have hitherto been detected in it. When placed under the microscope in a moist state, it resembles the film of a soap-bubble*; but, as it can be examined only as forming other textures, our observations must always be liable to error. It is that component of the vegetable structure, which constitutes its basis; or which, in its lax state, forms the cellular and the glandular textures and the epidermis; a little condensed, the vascular texture, and perhaps, still more consolidated, the ligneous fibre: consequently, it enters into the whole of the solid materials of the vegetable body.

The *Cellular texture* is formed from the membranous. It presents, in the parts of a plant where it is not compressed, the appearance of hexagonal cells, resembling those of a honeycomb. Grew, and some other botanical anatomists, had observed these cells, and believed they were little bags or utriculi lying contiguous to each other: he compares them to the bubbles on the scum of fermenting liquor; but, although the comparison be correct

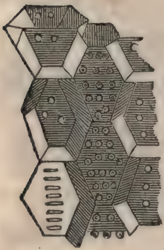
* Mirbel asserts that it is "d'une épaisseur variable selon "la nature particulière des espèces et l'âge des individus." *Elemens de Physiologie végétale, Partie* 1ere, *p.* 28.

in some stages of the formation of the cellular texture, yet it is incorrect, as far as regards its fully organized state. Mirbel, who examined them with more attention, first pointed out their real nature. He discovered that they are similar to the geometrical cells of a honeycomb, although sometimes of a longitudinal figure, and that the divisions of the membrane which forms

*a.*



*b.*



them are common to contiguous cells (fig. *a*); that they communicate with each other by means of pores and slits, about the three hundredth part of a line in diameter (fig. *b*)*; and that through these perforations the vegetable juices they contain are slowly transfused. The same author asserts also, that these pores are surrounded with borders, "petits bourrelets épais et calleux;" but this is doubtful. He describes the perforations as being few and scattered in the true hexagonal cells; but numerous and arranged transversely in regular series, in the longitudinal †. The membrane itself is so thin, that, when examined through a microscope, with

* It must be recollected that, in these representations and in all those of the vegetable internal structure which are to follow, the parts are very highly magnified.

† *Elemens de Phys. végét. Partie* 1ere, *p.* 29.

the light obliquely thrown upon it, it appears iridescent; but, as it has been already stated, its organization is too minute to be determined by any magnifying power with which we are acquainted. When put into water it is very quickly reduced to a kind of mucilage. This solution, however, takes place only when the vitality of the part is extinct; for, the cells in the living plant are often turgid with aqueous fluids, and yet they retain their proper consistence and form.

The cellular texture, in one form or another, enters into the composition of almost every vegetable organ. It is dry in some parts, but in other situations it receives and slowly transmits fluids; and in it, principally, the various secretions of the plant are deposited. Thus, it is generally filled with mucilaginous, resinous, oily, and saccharine juices; but sometimes the cells contain only air. In the bark of plants the cellular texture is found immediately under the cuticle, filled with a resinous juice, which is of a different colour in different species of plants, but most frequently green. In this situation it is the seat of the colour of the bark, in the same manner as the rete mucosum, or, more properly, the reticulated capillary membrane situated under the human cuticle, is supposed to give the colour to the skin; the reddish white in the European, and the black in the African. The cells

are filled with the same green juice in leaves, which are composed of a layer of cellular substance placed betwixt two layers of cuticle. The medulla or pith of plants is, also, composed of these cells, filled, in young and succulent plants and branches, with water, or watery fluids; but in older plants, and in the trunks and branches of trees, not succulent, they are generally empty. In the latter the shape and structure of the cells are most conspicuous, and easily observed. Thus, if a transverse or longitudinal section of a twig of *Spanish Broom*, in the second year of the growth of the twig, be placed under the microscope, or even a common lens, the pith of it displays in the most beautiful manner the hexagonal cells, the transparent iridescent appearance of the membrane forming their walls, and the situation of the communicating pores. It is well seen also by the aid of the microscope in the pith of many other plants. The petals of flowers are almost entirely composed of cellular texture, the cells of which are filled with juices fitted to refract and reflect the rays of light, so as to produce the brilliant and delicate tints with which the pencil of Nature has embellished these parts. In the same manner it enters into the composition of the stamens, the stigma, and even the pollen or fecundating farina of the flower. The fleshy parts also of succulent roots, and of pulpy fruits, are formed of this cellular texture filled

with different juices according to the nature of the roots and the fruit.

When the cellular texture is compressed, the cells are found forming nearly parallelograms, as in the leaf-stalk of the Artichoke, in which they have a somewhat tubular appearance; and, by the stretching of the membrane, the pores, which in the hexagonal cells are arranged without any order, are now very regularly disposed. The cells are proportionally more abundant in herbaceous plants than in trees; and in the younger than in the older branches. Senebier asserts that the partitions of the cells consist of a double membrane; but this is not capable of demonstration.

Such is the nature and appearance of the cellular texture. There is every reason for believing that it enters as a component into almost every part of the vegetable structure; and anatomy confirms the opinion as far as we have the means of ascertaining the fact. There are indeed some plants, as the Fuci and other marine vegetables, which appear to be altogether composed of cellular texture.

The next of the solids enumerated is the *Vascular texture.* It consists of hollow tubes of different forms and structure, which are capable, like the vessels of the animal frame, of conveying fluids. When a succulent stem is cut transversely, fluids are seen issuing from

different points; and, if the peculiar juices of the plant be of a milky or coloured nature, as in the Fig-tree or in any of the species of the genus Euphorbia, they are still more clearly perceived to issue from different points; for instance, the watery or colourless from one set, and the milky or the coloured from another. This circumstance leads us to conclude that the sap, or watery fluid imbibed from the soil, is carried in one set of vessels, and that the proper juices formed from the sap by the vital powers of the plant, are conveyed in another; or, that there are *conducting* and *returning* vessels: a fact which has been proved by experiment, and which we shall afterwards fully illustrate in speaking of the powers which move the fluids in the vegetable body.

The minuteness of these vessels requires the aid of the microscope for their examination; and even by its assistance as they are not easily seen, owing to their coats being in many cases transparent, and the fluids contained in them colourless, we are obliged, in order to render them more evident, to have recourse to coloured fluids, which are readily absorbed when the cut ends of twigs or branches are immersed in them; and the course of the vessels through the branch is thus marked by the colour. This mode of filling the vegetable vessels has been termed injecting, the intention of the process being the same as that which is

aimed at by injecting coloured wax and mercury into the animal vessels, when we wish to trace their course. The most eligible fluids for this purpose are decoctions of Brazil wood, and infusions of the skins of black grapes; and the plants likely to yield the most satisfactory results to the beginner, are the Periploca *Græca*, and the Aristolochia *Sipho**. The plant or twig to be injected should be cut with a very sharp knife, and its divided end immediately placed in the coloured infusion in a warm temperature: after a few hours the colour, in plants favourable for the experiment, may be traced into the leaves, the flowers, and even the fruit. This discovers the course of the conducting or adducent vessels; and when the operation is reversed, the twig being cut at its top, and inverted in the coloured fluid, we can trace that of the returning or abducent vessels. By placing transverse and longitudinal sections of twigs and parts of herbaceous plants thus treated under the microscope, we are able to ascertain the organization of the coats of the vegetable vessels. Some of the vessels, however, cannot be rendered more visible by this means, as they refuse to admit coloured fluids; and therefore any knowledge of

* This species of Aristolochia is a native of the Alleghany mountains; but it is now to be found in every botanical garden, and in most of the nursery gardens around London.

their structure can be obtained only by means of powerful microscopes.

Notwithstanding these facts, the existence of a vascular system in plants has been altogether doubted; and the subject has given rise to much controversial discussion. I might amuse you by a detail of the opinions delivered on both sides of the question; but little would be gained by such a display; and it will be much more satisfactory to you, to direct your attention to those facts only, which have been clearly demonstrated and which are generally admitted as correct.

The Botanists to whom we are chiefly indebted for the information we possess relative to the vegetable vessels, are Mirbel and Mr. Knight. The former examined them by means of microscopes of great power, and developed their real structure; the latter made many experiments on them by means of coloured fluids, which have thrown the greatest light on the vegetable physiology. Let us, therefore, take these two celebrated Phytologists as our guides in this part of our inquiries.

The *Vascular* or tubular portion of the vegetable structure composes a kind of net-work, owing to the frequent communication or anastomosis of the vessels with one another, which pervades almost every part of the plant. The particular vessels vary both in form and in the diameter

of their calibers. They are composed of the membranous texture, are firm, comparatively thick, and somewhat pellucid. Linnæus, following Gesner, admitted the existence of three descriptions of vessels only, which he named from their supposed uses. The first he called *vasa succosa*, because they carried fluids; the second, *utriculi*, on account of their being receptacles for preserving the vegetable juices; and the third, *tracheæ*, or air-vessels*. Willdenow† also arranges them according to their supposed uses, into, 1. air-vessels—*vasa pneumatophora*; 2. adducent vessels—*v. adducentia*; 3. reducent vessels—*v. reducentia*; and, 4. lymphatics—*v. lymphatica*: but every arrangement founded on the supposed functions of the vessels must be liable to objections. I think it preferable to adopt the arrangement of Mirbel, with some little variations, as it is constructed altogether on the forms of the vessels. He describes six different kinds of vessels‡; but the whole may be arranged under the three following genera:

* "Constant vegetabilia triplicibus vasis: 1. *Vasa succosa* "liquorem vehunt. 2. *Utriculi* alveolis succum conservant. 3. "*Tracheæ* aërem attrahunt." *Philos. Botan.* § 78.

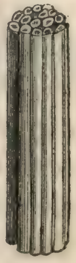
† Vide *Principles of Botany*, trans. § 236.

‡ "1°, Les vaisseaux en chapelet ou moniliformes; 2°, les "vaisseaux poreux; 3°, les vaisseaux fendus ou fausses trachées; "4°, les trachées; 5°, les vaisseaux mixtes; 6°, les vaisseaux "propres." *Elem. de Phys. végét.* p. 31.

1. Entire vessels.
2. Perforated vessels.
3. Spiral vessels.

1. The Entire vessels are, as their names import, simple tubes formed of imperforated membrane. They are cylindrical; and are generally in bundles, regularly disposed in the cellular part of the bark (fig. *c*). They are found in the young shoots of almost every kind of plant; and in the fasciculated state may be readily detected, and examined by the aid of magnifying-glasses, in the leaf-stalk of the common Fern, in the Arrow-head, Sagittaria *sagittifolia*, and in the common Hemp. In order to examine them individually, the bundles should be steeped in spirit of turpentine for a few days, by which means the vessels can be easily detached from one another.

*c.*



These vessels are intended to convey the proper juices of the plant; and are generally found filled with oils, and resinous juices; consequently, they are more numerous in plants, the juices of which are of a thick resinous nature; and these drying along with the condensed vessel in the bark, are the matters on which the medicinal virtues of barks in general depend. They are described by Mirbel under the name *vaisseaux propres* *, and are di-

* *Elémens de Phys. vég. Partie* 1ere, *p.* 31.

vided by him into two species—solitary and fasciculated. Those which he terms solitary, however, are, in my opinion, improperly regarded as vessels, being merely oblong cells, simple receptacles of secreted juices.

2. The PERFORATED VESSELS are cylindrical tubes, the sides of which are pierced with minute perforations variously distributed. They may be divided, according to the character of the perforations, into two species; *a. Cribriform vessels,* the perforations of which are simple pores, arranged in parallel series, transversely and equidistant over the whole surface of the tubes (fig. *d*, *e*). Mirbel denominates them "poreux." He asserts that each perforation is surrounded with an elevated border (bourrelet saillant), as represented in fig. *e*; an appendage which I have never been able to perceive; and observes, that they must not be regarded as continuous tubes, as they often separate, join again, sometimes disappear altogether, and always terminate in cellular texture. They are found in the substance of roots, in the formed wood of stems, branches, leaf-stalks and the central ribs of leaves; and are most numerous in hard woods, as of the Oak and the Chestnut. Their pores are so extremely small, that, in order to perceive them, a thin longitudinal

*d.*

*e.*

slice of the wood to be examined must be cut, and placed in a drop of pure water under a powerful microscope. It has not been accurately ascertained what kind of fluids is contained in these vessels.

A modification of the perforated vessels, having the appearance of a string of beads (fig. *f*), is named by Mirbel vaisseaux en chapelet, beaded vessels. It consists, as it were, of united portions of a porous tube, narrowed at the extremities and divided from each other by perforated diaphragms. This variety of the perforated vessels is found frequently in roots, and at the going off of branches and the attachments of leaves, being, says Mirbel, "intermediate between the large vessels of the stem and those of the branches; and it is by their means," continues he, "that the sap passes from the one set of vessels into the other *."

*f.*

*b. Annular vessels* are so named from the perforations being transverse and oblong, as if the tube were formed of rings, of the same diameter, placed one above another, and attached at some part of their edges, but not touching throughout the whole circumference. (Fig. *g*.) These vessels are in fact porous vessels, with oblong transverse pores, resembling in every respect, except in shape,

*g.*

* *Elém. de Phys. végét.* 1[re] *Partie,* p. 31.

the round pores of the last described vessels. They are also surrounded by a border (fig. *h*), and convey resinous and oily secretions. They are found in greatest number in the less compact woody parts of the plant. The centre of the majority of the species belonging to the family of plants named Lycopodium contain a thick cylinder, which is chiefly composed of vessels of this kind. Ferns also inclose many of them, in their woody threads; and several other plants, particularly the Vine, the wood of which is soft and porous, contain them in great numbers. Mirbel denominates them les fausses trachées; but as the analogy by which they are thus named is not just, I conceive we are more correct in calling them, from their structure, ANNULAR OR RINGED VESSELS.

*h.*

Each of these species of perforated vessels is occasionally seen forming different parts of the same tube; or one portion of it may present the cribriform characters, and another the annular.

3. The next set of vessels, the SPIRAL, has been known to Botanists since the time of Grew, who was the first that gave his attention to the anatomy of plants. They have been named *vasa spiralia*, and *fissuræ spirales*, from their appearance; and *tracheæ* from their resembling the tracheæ of insects, and from an unfounded opinion that

they were the vegetable organs of respiration*. They are the largest of the vegetable vessels; and in many plants their structure is visible to the naked eye. Thus, if a leaf, or a green twig of Dog-wood (Cornus *sanguinea)*, or of Elder (Sambucus *nigra)*, or the stem of any of the Lily tribe, or one of the fleshy scales of any bulb, as, for example, that of the Squill, be partially cut, then cautiously broken, and the divided portions carefully drawn asunder, the spiral vessels will be seen appearing like a screw, and their real structure become apparent. They are formed of a thread, turned in a spiral manner from right to left; as if, to use an illustration of Dr. Thomson, a fine and slender (he should have added flat) wire were wrapped round a small cylinder of wood, so that the successive rings touch each other, and then the cylinder be withdrawn; the form thus acquired by the wire will represent the spiral tubes†. (Fig. *i.*) The thread of which they are formed is elastic, opaque, silvery, shining, and flat; and in several plants, particularly the Banana (Musa *Paradisiaca)*, it is sufficiently strong to suspend the inferior portion of the twig, or the leaf, if it be not very large; but there is no reason for believing, as

*i.*

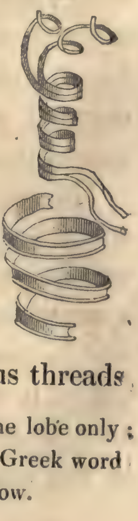
* Such was the opinion of Grew, Malpighi, Hedwig, and Linnæus.

† *Thomson's Chemistry*, 5th edit. vol. iv. p. 336.

Willdenow and others have asserted, that it is hollow, and forms a real vessel thus twisted in a spiral manner; or, that the larger hollow tube is an air-vessel, while the spirally twisted thread is a vessel carrying fluid. For, if we consider the smallness of the larger tube, and the flattened state of the thread of which it is formed, the impossibility of any fluid entering the smaller one, if it really existed as a vessel, may be easily conceived. According to Hedwig's observations, made with a microscope which magnified 290 times, he found that the apparent diameter of these air-vessels, as he supposes them to be, is one tenth of an inch; their real diameter must, therefore, be the 290th part of the tenth of an inch, or the 2,900th part of an inch. What then, I would ask, must the diameter of the supposed spiral vessel be, and what fluid could be conducted through it? The thread is sometimes double (fig. *k*); and Mirbel asserts, that it is furnished with a glandular border (fig. *l*).

k.

l.



These vessels are found in great numbers in monocotyledonous plants *, as in the centre of the ligneous threads

* These are plants, the seeds of which have one lobe only; the term monocotyledon being a compound of the Greek word μόνος (monos), one, and κοτυληδὼν (kotulēdon), hollow.

which exist in the stems of Grasses, and in Palms. They are numerous also in most herbaceous plants; and particularly in aquatics of a lax texture. They are seldom detected in the root, and never in the bark; but are situated round the medulla of the young shoots of trees and shrubs; whence bundles of them are given off, and enter the middle rib of leaves, to be distributed through them under their upper surface. They have been detected, also, in the calyx, or flower-cup, and other parts of the flower; and Gærtner asserts that they are evident even in the seed-lobes. The spiral vessels, in their course, proceed always in straight lines, without any deviation; whereas all the other vegetable vessels often take a curved direction. It is into these vessels that coloured injections most easily enter; and when an annual twig of the Fig is thus injected, they are seen in a transverse section of it, like red dots around the pith, placed within an external circle of the vessels, which contain the succus proprius, or milky juice of the plant.

It cannot be affirmed that the varieties of form, which we have pointed out in the vegetable vessels, is of the same importance as the difference which exists in the structure of the arteries and veins of animals. There are, indeed, some plants in which three of the modifications of structure, according to Mirbel's observation, are found in the same tube. In the Butomus *umbellatus*,

Flowering Rush, says that author, "I have seen long portions of vessels present, at intervals, the appearance of an unrolled trachea, a transversely cleft vessel, and a porous vessel."

Besides these vessels, Hedwig imagined there existed lymphatic, or absorbing vessels, opening upon the cuticle, and forming a circle round the exhaling pores: a doctrine, which has been adopted by Willdenow and others; but which Mirbel justly combats, alleging "that the sides of the cells which terminate in the cuticle, and the fragments of which remain fixed to that pellicle when it is detached, have been mistaken for lymphatic vessels by Hedwig *."

Mirbel mentions another set of vessels, which he denominates little tubes; but they may rather be regarded as tubular cells, than vessels, being closed at the extremities. They resemble, very much, stretched cellular substance, except that the membrane composing them is less transparent, and of a greater consistence. The solidity of plants depends very much on the quantity and density of these cells, which are filled with thick and coloured, or thin and colourless juices, according to the nature of the plants in which they exist.

Such is the vascular system of vegetables.

* *Elém. de Phys. végét.* 1ère Partie, p. 40.

As we do not intend, at present, to enter into any account of the uses of the vessels we have described, we will only observe, that as all vegetables take up nourishment from the soil, and change it into juices different from each other, and which must be preserved from mingling together during the life of the plant, we might (à priori) suppose that plants must necessarily possess a vascular system: microscopic anatomy proves the fact, displays the numerous ramifications, and general distribution of the vessels: observation shows that their elongation increases the bulk and growth of the plant, and that they perform the most important functions in the vegetable system. I may here also remark, that whilst the tubes, or vessels, which have been described, are intended chiefly for the longitudinal progression of fluids, the lateral transmission of the vegetable juices is performed, perhaps solely, by organized pores and slits, such as have been described in the perforated vessels, and in the sides of the cells. But the account of the manner in which this function is performed, must be postponed for our future consideration.

The structure of the *Glandular texture*, as far as relates to the interior of the vegetable body, is much more difficult of demonstration than that of any of the general solid components which have been already noticed: but, when the im-

possibility of attaining an accurate knowledge of the glands of the animal body, which are large and visible to the naked eye, is considered, it will not appear wonderful that our remarks on this part of our subject are drawn rather from analogy than from actual observation. When, however, we reflect on the nature and diversity of the vegetable secretions, and that plants possessing the most opposite properties rise from the same soil, there appears to be no medium by which the absorbed aliment can be so altered in its characters, except by that of a glandular system. I am willing to admit that the simplicity of the vegetable structure is astonishing; and that effects are produced in plants, by means which are apparently very inadequate, when we regard them with a reference to the animal economy: yet, still, when the eye glances over the number and variety of vegetable products, there is much reason for supposing, that the simple transfusion of fluids can scarcely be sufficient for the production of these changes. We know that the laws of chemical affinity, in the temperature in which they take place, are inadequate to the effect; and, besides, many of the changes produced, particularly those which fit the sap to be assimilated into the substance of the plant itself, are directly contrary to the laws of chemical affinity, which operate in destroying these combinations, as soon as the vital

principle of the plant ceases to act. Although, therefore, we cannot by demonstration prove the existence of internal glands in vegetables, yet we have the strongest analogical proof in favour of the supposition that they do exist. The pores and clefts of the cells and the vessels which have been described are surrounded by opaque regular borders; and even the flat thread which forms the spiral vessels is edged with a similar border. These bodies are regarded by M. Mirbel as glands; and he conceives the opinion receives weight from the circumstance of the mucilage, which is changed into the organized tissue, being found always collected in greatest quantity around those vessels which are most studded with these opaque borders. This supposition is extremely probable, and is one of those which, if they cannot be confirmed, cannot be positively denied. If, as we suppose, vegetable glands exist, they must necessarily enter as a general component into the structure of every plant.

Besides the glands, the existence of which in the interior of the plant, if not demonstrable is too probable to admit of much doubt; there are also external bodies, which all Botanists have agreed in considering as glands, and which, in general, separate, as an excretion, some peculiar fluid *. Thus, honey, or a nectarious fluid, is

* "Glandula," says Linnæus, "est papilla humorem excernens." *Philosophia Botanica*, § 84, 6.

secreted at the base of the petals or coloured floral envelopes, in the greater number of plants; on the stalks of others, a viscid substance is thrown out; and on some, little sharp bristles are planted, which are perforated, and through which a very acrid fluid is ejected into the wound which they make in the cuticles of animals. Examples of the first are to be found in almost all flowers; we observe the second in the species of the genus Silene, called Catch-fly, and in many other plants; and the bristles of the Stinging Nettle supply a well-known instance of the last.

Of the structure of these glands, although they are external, yet very little is known; and microscopes of the greatest magnifying powers present them as masses of cellular substance only, with vessels passing on to their centre, without developing any other particular organization, which might lead to the formation of a theory explaining the mode in which they perform their functions. These, however, are, in some degree, obvious from their effects; and afford more than probability to the idea that vegetables possess a glandular system. We shall have occasion to point out, and explain, the particular forms and functions of these external glands in different plants, when we come to examine the parts on which they are situated.

The *Ligneous fibre* is a very minute, firm,

elastic, semi-opaque filament, which, by its cohesion with other filaments of the same kind, forms the proper fibres, or layers of longitudinal fibres, that constitute the grain or solid part of wood. It enters, also, into the composition of another set of layers, that traverse the longitudinal, named divergent. It is intended to give support and firmness to the vegetable body, and hence is found in greater abundance in trees and other perennial plants; and according to the number of the ligneous fibres in each bundle of layers and the force of their cohesion, the wood of different trees possesses a greater or less degree of hardness. But, although wood is found of various degrees of consistence, yet, as Count Rumford has suggested, it is probable that the ultimate fibre is the same in all plants*.

Whether the ligneous fibre be of original formation similar to the muscular fibre of animals, or condensed membranous or cellular texture, or an obsolete obstructed vessel as Hedwig supposes, is yet undetermined. It is so intimately united with the cellular texture containing the vegetable secretions, that it cannot be procured pure for examination, without the aid of chemical agents to separate these adjuncts. If a thin shaving of well-dried wood be first digested in boiling water, then

* Nicholson's Journal, vol. xxxiv. p. 319.

in alcohol, and lastly in ether, every thing soluble in it will be extracted by these liquids, and the insoluble part which remains be found to be composed of interlaced fibres, easily subdivided and having some degree of transparency: these are the ligneous fibres. They have neither taste nor odour, and remain unaltered by exposure to the atmosphere: but although insoluble in water, alcohol, or ether, the fixed alkalies and mineral acids dissolve and decompose ligneous fibre. The relative quantity of this fibre in any plant may be pretty accurately ascertained, by exposing a given quantity of the wood to a moderate fire, in close vessels, for a number of hours sufficient to convert it into charcoal; for, as the wood only becomes charcoal and the other parts are dissipated, the proportional weight of the charcoal obtained shows the quantity of the ligneous fibre contained in the wood. By experiments of this kind, carefully performed on the wood of the Poplar, the Lime, the Fir, the Maple, the Elm and the Oak, Count Rumford ascertained that the quantity of ligneous fibre in each of these trees was equal to nearly nine twentieths of their wood in its natural state *.

The *Epidermis* is that portion of the vegetable structure which is exterior to all the others;

* *Gilbert's Annalen der Physick*, xiv. p. 25; and *Thomson's System of Chemistry*, 5th edit. vol. iv. p. 186.

at least to those which retain their vitality in the vegetating state of the plant: or it is that part which is interposed between the living organs of the individual, and all extraneous substances. In this respect it resembles the cuticle of animals; but Botanists have been too fond of tracing this analogy, which has, not unfrequently, biassed their observations, and led to erroneous conclusions. It extends over the surface of every part of the plant; from that of the delicate petal of the flower, to that of the leaves, the branches, the stem, and the root; but, except in young stems and roots, it is not the exterior part of those organs of the plant; the coarse rugged surface of older roots and stems being exterior to the real epidermis. It is common to every kind of plant, nor can we conceive that any one can exist without it. Botanists, as I have already stated, are very fond of drawing an analogy between the epidermis of plants, and the animal cuticle; and the resemblance, in many respects, is conceived to be closer than it really is; but there is, nevertheless, in some circumstances a very striking analogy. The vegetable epidermis may be separated from the parts which it covers, by raising it cautiously with a knife; but this is more easily effected by maceration and boiling. It is more readily separated from the cellular substance it covers in the leaf, than in any

other part of the plant; and for this purpose I would recommend to the student the leaf of any of the Lily tribe, before the stem shoots up; or of the Lettuce (Lactuca *sativa)*, or that of Sorrel (Rumex *acetosa)*; but even in these, some of the cellular matter is always detached in separating it; and to this circumstance is perhaps to be attributed the variety of opinions which phytologists have advanced regarding its structure.

The epidermis appears at first of a green colour on the young stems and branches of almost all plants; but it changes to different hues, according to the age of the part it covers. According to Du Hamel, it is composed of fine, but tough fibres, which are interwoven together; and every where interspersed with pores, which permit the mouths of the absorbing, transpiratory and air vessels to open to the atmosphere. Comparetti also describes it as composed of fibres, interwoven so as to form hexagonal meshes, the areas of which are filled up with opaque or diaphanous vesicles, inflated as if extended with air or water, and having a small black point in the centre. Mr. Bauer, on the contrary, conceives the structure to be altogether cellular, and varying in different plants*. My own observations lead me to adopt the opinion of the elder Saussure,

* *Tracts relative to Botany.* Lond. 1805.

that the true epidermis is a fine, transparent, unorganized pellicle *. The pores, by which the insensible perspiration escapes, are so minute, that they are quite invisible, and with difficulty permit the passage of air through them. Thus, if an apple be put under the receiver of an air-pump, and the air withdrawn, the cuticle of the apple will be lacerated by the dilatation of the air contained in the pulp of the fruit. There are oblong pores also in the cuticle of herbaceous plants in particular, as was first observed by Decandolle, who named them cortical pores. The size of these is considerably greater than that of the former; and varies in different plants.

The epidermis seems to be entirely destitute of longitudinal vessels. In herbaceous plants, and in young and succulent twigs, it is, with a few exceptions, colourless and transparent; the apparent colour being produced by that of the juices in the cellular substance immediately beneath it, in the same manner as that of the human cuticle is produced by the colour of the capillary web which it covers, and which is filled with different coloured fluids in different races of men; white in the inhabitants of the temperate zones, and black, or brown, in those of the torrid

* *Obs. sur l'Ecorce des Feuilles.*

regions of the globe *. When the epidermis is applied very closely to the cellular layer below it, which is the case in herbaceous plants, and in the young twigs of trees and shrubs, the greater portion of the light is transmitted through the cuticle, and reflected from the cellular layer, and not from the substance of the cuticle; so that the colour of the herbaceous stem, or of the twig, is, in this case, that of the cellular layer, and not of the cuticle itself; yet in trees and shrubs, which annually renew the cuticle, as the Plane, the Birch, the Currant and many others, the epidermis, when it begins to peel off, becomes more opaque and does not transmit the light, but reflects it from its own surface. Thus the old cuticle of the Plane is dark coloured, while the new is of a light green hue; the stem of the Birch, from which layers of epidermis are continually peeling off, is white, while the young branches are brown; and the old branches of the Currant are dark brown, while the young shoots are of a very light green hue. In some plants, instead of being thrown off in

* "On peut donc concevoir le corps reticulaire comme "un systême capillaire général, entourant l'organe cutané, et "formant avec les papilles une couche intermédiaire au corion "et à l'épiderme. Ce systême ne contient, chez la plupart des "hommes, que des fluides blancs. Chez les nègres, ces fluides "sont noirs. Ils ont une teinte intermédiaire chez les nations "basanées." *Bichat, Anat. Générale, &c. tome* 4[me], p. 657.

plates, or in layers, the old cuticle is reduced into powder.

Although the epidermis is not cast off from all plants in this manner, yet, it is constantly renewed; and, where it remains, the old cuticle cracks as the diameter of the stem of the tree, or of the branch, increases: it is then gradually pushed outwards, and the accumulation of successive layers, in this manner, forms the rugged coats which characterize many trees, as the Elm and the Oak. This renewal of the epidermis in vegetables is similar to what takes place in animals. The snake, for example, casts his skin annually, as do also the crab, the lobster, the spider and many other insects; and the cuticle of the human body often peels off, particularly after some diseases, as scarlet fever for instance, and on the application of acrid matters to the skin. In animals, however, when destroyed, it is again regenerated; but in vegetables, this occurs on the stems and branches of perennial plants only; for on annual plants, and on the leaf and flower, it is not renewed after being destroyed. The vegetable epidermis is capable of extension; but this is less considerable than has been supposed; and as there is a constant renewal, there must be a proportional increase or growth of its parts, so that it is not simply extended to enable it to cover

a greater portion of surface; but new cuticle is added to produce this effect.

The use of the epidermis is to keep the parts beneath it together; and to regulate the perspiration and absorption of the plant. It is calculated also to defend the parts it covers from humidity; for which purpose, it is covered with a waxy secretion. The powers of the cuticle in regulating these functions is fixed according to the nature of the plant. In succulent plants, which require much moisture to be retained in their leaves, the cuticle is so constructed as to assist absorption, but rather to prevent transpiration. Thus, if a leaf of the Aloe be cut off, it will remain a very long time, even when exposed to the sun's rays, before it shrivels; but, if in this state it be exposed to damp air, or thrown into water, the absorption is so rapid that it will regain its original plumpness and size in a few hours. A fine proof of that overruling Wisdom which fits every thing for the fulfilment of the purposes of its creation: for, in this instance, the Aloe being a native of a dry arid soil, and a warm climate, it could not long exist if the perspiration from the surfaces of its leaves were considerable, but on the contrary it draws a great deal of moisture from the atmosphere by absorption. Another use of the epidermis is to prevent the destruction of the parts it covers: for, as it is in the vessels of the inner bark, as I will afterwards

demonstrate, that the greatest activity, irritability, and degree of vital energy reside, if that part be wounded to any considerable extent, so that the external air gets access to it, exfoliation, and the death of the part, and sometimes that of the whole plant, follow; the cuticle forming, as Sir J. E. Smith elegantly expresses it, "a fine, but essential "barrier between life and destruction*."

Mirbel † combats the idea of the epidermis being a distinct organ, and supposes it to be the external layer of the cellular membrane condensed, and altered by exposure to the air and light. But although I admit that the cuticle be nearly the same as the parietes of the cellular tissue which it covers, yet, it is nevertheless a distinct organ. The simple exposure of the cellular membrane will not form epidermis; but, on the contrary, when the cellular substance is exposed, it is more apt to exfoliate; and when the wound becomes healthy, it is then only that cuticle is reproduced. During this process the new epidermis proceeds from the sides of the wound, gradually extending over it, in the same manner as in a wound of the human body. The very close connexion of the epidermis and the cellular substance can be no argument against our opinion; for, although the

* *Introduction to physiological and systematical Botany*, 2d edit. p. 18.

† *Elémens de Phys. végét.* 1ere Partie, p. 35.

flakes of epidermis which are cast off annually by the Plane tree, and some other trees, consist of cellular substance also, yet, the cuticle is already formed under the flakes before they fall, and therefore it cannot be in these cases produced by the action of the air, and light. On examination of these flakes, the epidermis appears to be distinct from the plate of cellular substance which separates with it. Mirbel himself, indeed, is obliged to modify his objection, and adds, But, although the epidermis of vegetables does not resemble that of animals, and is certainly the external part of the cellular substance, yet, it is no less true that secondary causes modify its nature, and it consequently becomes an organ the functions of which are very distinct and important *. Such a concession is all that can be demanded. That the human cuticle is a distinct organ has never been denied, and yet we know that it is equally without vessels and nerves. On the same principle, therefore, the vegetable epidermis must be admitted to be a distinct organ; and

* "Mais, quoique l'épiderme des végétaux ne ressemble "pas à celui des animaux, et qu'il soit formé certainement par "la partié extérieure du tissu cellulaire, il n'est pas moins vrai "que des causes secondaires modifient sa nature, et qu'il "devient par le fait un organe dont les fonctions sont très- "distinctes et très-importantes." *Physiologie végétale*, vol. i. p. 89.

the modifications of it in different plants are more numerous than among animals. The illustration of these varieties must be deferred, till we come to consider the structure of the bark, of which the epidermis is usually considered a layer.

Such are the principal solid components of the vegetable body. Other solid matters certainly enter into the structure of some plants; but, as those are not common to the vegetable race, they cannot be classed amongst the general components. Perhaps, also, all the parts which have been examined may be resolved into modifications of the membranous and cellular textures, which might consequently be regarded as the only real solid vegetable components; but, although we allow that the vessels, ligneous fibre, glands, and epidermis most probably are composed of membranous, or cellular texture, differently modified, yet, as each of these parts possesses very distinct functions, such a refinement would only throw obstacles in our way towards the attainment of truth; I have, therefore, considered it preferable to regard them as distinct components.

### GENERAL FLUID COMPONENTS.

Vegetables, by their vital energy, increase in bulk, and augment the quantity of solid matter they contain, consequently the principles of the solids must be contained in the particular fluids which they select and imbibe from the soil; but in what manner the fluids are changed into solids, and whether any of the solid matters be taken up ready formed, or whether they result from a transformation effected solely by the action of the vegetable vessels; are subjects of consideration upon which, in the present stage of our inquiries, it would be premature to enter. These fluids, however, after being absorbed by the roots, enter into and fill the cells and vessels of the plant, and form a very considerable portion of the bulk of the vegetable body. As soon as they enter the plant, they constitute its SAP, or common juice, to the nature of which, as it is one of the general components of vegetables, we must now direct our attention.

Were we about to examine the moving powers by which the fluids selected from the soil, and absorbed by the roots of plants, are carried forward through the vessels, we would demonstrate that although these moving powers operate at all times during the life of the vegetable, yet, that

their action is most energetic in spring and at midsummer, at which periods, therefore, a much greater quantity of fluid is found in the vegetable vessels. As, however, the simple examination of the sap itself is our present object, it is sufficient to state the fact; and to know that, at these seasons, when an incision is made through the bark and part of the wood of most kinds of trees, or a hole is bored in the trunk, a fluid exudes in considerable quantity. This is the sap, or common juice. It is in the same situation, for the purposes of the plants, as the chyle of animals is, while it is yet in the thoracic duct, and before it is mingled with the blood, and exposed in the lungs to be fitted for the purposes of the animal. Neither is in a proper state for yielding the various secretions, and adding, by the process of assimilation, to the growth of the plant, or of the animal; but the analogy goes no farther. In the animal, the digestive powers of the stomach and the action of the mesenteric glands so change the food taken into it, that no chemical analysis of the chyle produced from it could lead to an accurate knowledge of the kind of food, which had been employed by the animal; but, in plants, the food is already prepared in the ground before it is absorbed by the roots, and, therefore, were it possible to obtain the sap from the vessels very near to the extremities of the roots, we should be en-

abled to discover, with a considerable degree of accuracy, the real food of plants *. This, however, cannot be accomplished; and as the sap, in its progress, dissolves some ready-formed vegetable matter, which had been deposited at the end of the former autumn, in the upper part of the root and at the base of the stem, its original properties are thus altered; and the farther the part, which is bored in order to procure the sap, is from the root, the more vegetable matter this fluid is found to contain. This fact was first noticed by Mr. Knight, who ascertained that, owing to this deposition, the wood of the stem, and the large branches of trees, have a greater specific gravity, and contain more soluble extractive matter when cut down in winter, than in spring, or early in summer: on this account, although there is reason for believing that the food of almost all vegetables is the same, yet, the sap, in the state in which we can obtain it, differs in different species of plants; and, therefore, no just idea can be formed of its nature from the most accurate analysis of it, when procured from any single plant. Were it possible, however, to obtain the

* It has been supposed that the roots of plants absorb, indiscriminately, all the soluble matter contained in the soil on which they grow; but were this the fact, many more substances would be found in the vegetable body, than have yet been discovered in it.

sap completely free from the peculiar juice of the plant, it would be very probably found nearly the same in all plants. From an examination of it, such as it can be obtained, we are enabled to draw some general conclusions; and by comparing the analysis of the sap of many different plants together, we discover those components which are most frequently present, and consequently form an opinion, approximating to the truth, of the real nature of the sap.

When a tree is wounded, in the manner we have described, in the spring, it is said to bleed; and if the wound be considerable, and in the principal stem, the tree being thus drained of its fluid, soon dies *. Any quantity of sap may be collected by this mode of wounding trees, and the

* When we reflect how early this fact must have been known, it is remarkable that so little progress has been made in developing the power by which the sap is carried forward through the plants. The rudest nations are acquainted with the fact that trees bleed when wounded; and from a knowledge of its consequences, the Asiatic nations, in their wars, commit the greatest injuries which their opponents can suffer. The Palms in Asia being as necessary for supplying the ordinary food of the natives, as grain is in Europe; when an hostile army enters the territory of an enemy, they cut notches with hatchets in all the Palms which they meet with; which occasions the sap, and the other juices of the plants to run out; and the Palms either die altogether, or are rendered abortive for that season.

less progress vegetation has made, it is obtained in a purer state. It should, therefore, be drawn very early in the spring, before the leaves expand, and as near to the root of the plant as it can easily be obtained, if we wish to examine its chemical properties.

When the sap is thus drawn from a tree, it usually appears nearly as colourless and limpid as water, has scarcely any taste and no particular odour. A phial containing a certain quantity of sap weighs heavier than the same phial, containing an equal portion of distilled water; so that the specific gravity of sap is greater than that of water. If it be kept for some time in a warm place, it undergoes sometimes the acetous, at other times the vinous, and in some instances even the putrefactive fermentation. These differences would indicate a great disparity in the components of the sap of different vegetables; but there is every reason for thinking that they depend more on the admixture of the proper juices, which, as I have already stated, are always more or less mixed with the sap, as we can obtain it; and it is probable, that the sap of different plants differs more in the proportional quantity of these juices mixed with it, than in the nature of its components. The rapid vinous fermentation of some kinds of sap is taken advantage of in warm climates for economical purposes. From the top of the Cocoa-nut tree

the natives of India extract the sap, mixed undoubtedly with the proper juice, by making an incision with a sharp knife overnight, and suspending under it a vessel to receive the fluid as it exudes. This liquor, next morning before the sun is hot, is a pleasant, mild, cooling beverage; but before evening, it ferments and becomes powerfully intoxicating. In Ceylon, arrack is distilled from this fluid, which is named toddy; and it, also, yields a coarse black sugar, called jaggery. As, however, in this case the sap is combined with the proper juice of the tree, the extraordinary effects of the rapid fermentation must, in a great degree, be ascribed to it. It is to the same cause also, as I before noticed, that we must ascribe the difference in different saps, particularly the saccharine and acid qualities, which they sometimes present even when newly drawn. Thus we are told that sugar is extracted in the proportion of ten pounds from every two hundred of the sap of the Acer *saccharinum*, Sugar Maple. But the sap is so mixed with the peculiar secreted juices of the plant, when it is drawn from the tree for this purpose, that it can scarcely be considered as yielding the sugar. According to the observations of Mr. Knight, sap always contains a considerable portion of air. It, also, differs in its specific gravity according to the distance from the root at which it is taken, the gravity increasing in the direct

ratio of the distance, which appears in some degree to arise from the solution of deposited matter in its progress, but, perhaps, more from the transpiration of the plant throwing off a large proportion of the watery part of the matter taken up from the soil. Such are the sensible qualities of sap; its chemical properties and composition are discovered by tests and analysis by heat. I shall first mention some experiments I made on the sap of the Vine, and then detail the results of those made on some other saps by Vauquelin a celebrated chemist of the French school.

On the eighth of April, when the thermometer was at 68°, and a few leaves of the Vine, which was the subject of experiment, had already expanded, I cut off the extremity of the lowest of the branches, and introduced the cut end of the part which remained fixed to the Vine, into a six ounce Apothecaries' phial. On the following morning, about three ounces of a clear, limpid, colourless fluid, like water, was found in it. It had no perceptible taste, except a slight mucilaginous feeling on the tongue; no odour; and weighed rather heavier than distilled water. On pouring a little of the Tincture of Litmus into it, it was very slightly reddened, thereby indicating the presence of an acid *. The oxalic acid almost

* Dr. Prout, who examined the sap of the Vine, found that the specimen which he procured did not differ in specific gravity from pure water; nor did it alter Litmus paper.

immediately rendered it milky, and threw down a white precipitate. The acetate of barytes threw down a white flocculent precipitate; and by acetate of lead (Goulard's extract), a white curdy precipitate was also produced. No change was effected on it by the solution of ammonia, nor by that of gelatin: nor was any dark hue communicated by the sulphate of iron. The addition of alcohol to this sap threw down a light flocculent precipitate, of a mucous nature. The sulphuric acid added to it, occasioned a slight effervescence, and evolved the odour of acetous acid. The conclusions which may be drawn from these appearances is, that this specimen of the sap of the Vine contained acetate of potash with perhaps an excess of acid; carbonate of lime, vegetable mucilage, some albuminous matter and water. As no effect was produced by the additions of the sulphate of iron and the solution of gelatin, we conclude that it contained neither tannin nor gallic acid, and therefore possessed no astringent property: a proof that the sap which we tried was pretty pure, for some of the secreted fluids of the Vine are both very acid, and considerably astringent. The small quantity of sap which was obtained, owing to the rather advanced state of the season, for such an experiment, prevented the proportions of the different ingredients from being ascertained.

M. Vauquelin, as I have already mentioned, made the most interesting experiments, which have,

yet, been attempted on sap. As he does not, however, mention the state of the trees, from which the sap for his experiments was taken, the result of the analyses affords some reason for believing, that the sap was not in the purest state. He examined the sap of the Elm, Ulmus *campestris*, collected towards the end of April, the beginning of May, and the end of May. The result of the first analysis was, that 1039 parts of this sap consisted of 1027·904 of water and volatile matter, 9·240 of acetate of potash, 1·060 of vegetable matter, and 0·796 carbonate of lime. The second analysis of the sap collected at the beginning of May afforded a greater proportion of vegetable matter, less acetate of potash, and also less carbonate of lime: and in the third analysis of that collected at the end of May, the quantity of the acetate of potash was still more diminished, and also that of the carbonate of lime *. In all he found slight traces of sulphate and of muriate of potash. From two different analyses of the sap of the Beech, Fagus *sylvatica*, procured also at different periods of the same season, he obtained water, acetate of lime, free acetic acid, gallic acid, and tannin, with some vegetable extractive and mucous matter †. In the same manner he examined the sap of the Common Hornbeam, Carpinus *sylvestris*, collected in March and April, and found in it, acetate of potash,

* *Annales de Chimie*, t. xxxi. p. 21.

† Ibid. p. 26.

acetate of lime, sugar, mucilage, vegetable extract, and water. In the sap of the Common Birch, Betula *alba*, he found acetate of lime, acetate of potash, acetate of alumina, sugar, vegetable extract, and water. In all the specimens thus analysed the quantity of vegetable matter was found to be greater in the sap drawn late in the season, than in that collected at an earlier period of it.

If we are to consider these results of Vauquelin's experiments as pointing out the real composition of sap, we can gain no information from his labours; as from the results of them we should suppose that every different kind of tree must have sap of a description peculiar to itself, which, both the analogy of the animal kingdom, and the knowledge we have of the nature of soils, inform us cannot be the case. It is probable that the water, the acetate of potash, and the carbonate of lime, are taken up from the soil, and enter as general constituents into the composition of sap; but the mucilage, the sugar, the extractive, the gallic acid, the tannin, &c. are undoubtedly produced by the vegetable system itself, and must, therefore, vary in different plants. As we shall afterwards find that all the productions of the vegetable system can be resolved into carbon, hydrogen, and oxygen; each production differing in its composition from another in the proportion only of its components; it is easy to comprehend that, as from the water

the hydrogen and oxygen may be obtained, and the carbon from the acetate of potash and carbonate of lime; Vauquelin was authorized in concluding that the acetate and carbonate, which are found in a diminished quantity in sap drawn at an advanced season, may be decomposed by the vital action of the growing plant, and the carbon they yield with the hydrogen and oxygen go to form the vegetable matter. But although the acetates are found in soils, yet they are not in any considerable quantity, nor sufficient to supply all the carbon wanted for the purposes of plants: it is, therefore, probable that if sap could be examined in its purest state, it would be found to consist of water, holding carbonaceous matter in solution, acetate of potash, carbonate of lime, and now and then some siliceous and aluminous particles, suspended in the solution, and of sufficient minuteness to enter the mouth of the absorbents of the root. It is probable, also, that there is little difference in the pure sap of all plants; but as the first changes take place undoubtedly in the roots, and the modifying power of these parts must be different in different kinds of plants, the changes which occasion the varieties of the sap, are sooner produced in some plants than in others. On these differences of the ascending fluid, however, the secretions certainly do not depend; for, if that were the case, the grafted branch would not bear fruit and leaves,

and have secretions deposited in its cells similar to those of the parent, but to those of the stock. We know, however, that this is not the case; for, if the branch of a Pear-tree be engrafted on an Apple-tree, the Pear branch will produce leaves, flowers, and fruit, and have the new wood formed on it exactly the same as the Pear-tree from which it was cut, although the first modifications of the nutriment imbibed by the roots of the Apple stock are different from those of the parent Pear: but as soon as it arrives at the secreting organs of the Pear branch the alterations it undergoes are exactly the same as if the branch had remained attached to its parent stem; and consequently the wood, leaves, flowers and fruit, will have the characteristics of its original.

The modifications which take place in the roots of plants, throw considerable obstacles in the way of obtaining a perfect knowledge of this part of the vegetable economy; for, to obtain such a knowledge of the nature of sap would require an examination of that fluid in a greater number of different species of plants, than the opportunities, and the period of any life, permit. All that we can aim at, therefore, in the present state of our knowledge, is the formation of a probable hypothesis, rather than the attainment of truth deduced from certain experiments. In this mode of viewing the subject, we may regard the sap

of plants as consisting of *water* which is its principal component, *carbonaceous matter, acetate of potash,* and *carbonate of lime*;* which ingredients are decomposed by the vital powers of plants, and new combinations of their constituents produced by the same powers, so as to form the different parts of which a plant consists. The large portion of vegetable matter contained in the first sap, as we have already noticed, must have been previously deposited in the cells of the root, and taken up by the water of the sap in its progress upwards: and air which is also found in sap, as Mr. Knight has demonstrated, is either the produce of vegetation, or is taken in by the roots dissolved in the water of the soil†.

Such is the nature of the sap. In spring and at midsummer it forms a large portion of the vegetable body; and is carried forwards through the vessels, with an impetus sufficient to raise it to the summits of the highest trees, until arriving at the leaves, in

* The enumeration of these ingredients as the general components of sap, cannot be objected to because many other saline and earthy matters are occasionally found in sap; those depending altogether on local circumstances affecting the soil.

† Sir H. Davy, in his Lectures on Agriculture, has adopted the opinion of Feburier, that the sap is found in two states; one kind in the vessels of the alburnum, containing chiefly saccharine matter, mucus and albuminous matter, and another in the bark, containing tannin and extract; but I am not inclined to regard any juice found in the bark as ascending sap; and, therefore, cannot subscribe to this opinion.

which it is exposed to the action of the air, and light, the great quantity of water it contains becomes no longer necessary, and is thrown off by perspiration; whilst the *succus proprius*, or peculiar juice of the plant, from which all its secretions are formed, is produced by the changes resulting chiefly from this exposure. We have, therefore, next to proceed to examine the nature of this peculiar juice, as one of the general components of plants.

## GENERAL FLUID COMPONENTS—THE PROPER JUICE.

I should be anticipating the inquiries we have to make into the physiology of leaves, were I now to attempt to explain to you how the sap is conveyed into these organs, to be exposed to the action of light and air; or, by what means those changes are effected in them, by which it is converted into the proper juice, *succus proprius:* at present we have to examine this fluid merely as a general component. It is, however, necessary to remark, that although we may admit with Malpighi that the proper juice is to the vegetable system, what the blood is to the animal, yet, the functions by which it is prepared from the sap must be modified in different kinds of plants, since it exhibits some peculiar characteristics in each kind.

When a plant is cut through transversely, the proper juice is seen issuing from both divided sur-

faces, but in greatest quantity from the open orifices of the divided vessels in the part farthest from the root; a fact which is ascribable to the progression of the proper juice being invertedly to that of the sap, or from the leaves towards the roots. It is very often mixed with sap, and cannot be distinguished from it by colour; but in many instances it is coloured or milky. Thus, if a twig of any of the species of Spurge (Euphorbia) be cut, the proper juice issues from the wound in the form of a resinous milky emulsion, and may be obtained in considerable quantity. This juice in the majority of plants is, as I have said, colourless; it is, however, yellow in some, as in the Celandine (Chelidonium); red in others, as in the Bloody Dock (Rumex *sanguinea)* and the Logwood tree (Hæmatoxylon); deep orange in the Artichoke (Cynara *Scolymus)*; white, as in the Spurges (Euphorbia), the Dandelion (Leontodon *Taraxacum*), the Fig (Ficus), &c.; blue in the root of Pimpernell (Pimpinella *nigra)*; and green in the Periwinkle (Vinca). The colour is sometimes changed by the exposure of the exuded juice to the air. Thus Opium, which is the proper juice of the white Poppy, is white and milky when it exudes from the incisions made in the plant for the purpose of obtaining it; but changes to a yellowish brown hue by exposure to the air. The plantule also of the French or Haricot Bean, when wounded, emits a reddish proper

juice, which after being exposed to the air for a short time assumes a deep indigo blue tint: and the juice which exudes from incisions in the leaves of the Soccotrine Aloe, yields, by simple exposure, according to the statement of M. Fabroni, a very deep and lively purple dye, so permanent, and resisting so completely the action of acids, alkalies, and oxygen gas, that he thinks it may be used as a pigment in miniature painting; or as a dye for silk, which it will effect without the use of any mordaunt*.

It is necessary to mention that Mirbel, and some other Botanists, have fallen into an error, in confounding together the proper juice, and the secretions of plants. It is from the proper juice that the secretions are formed; but it must undergo another elaboration, something similar to that which the blood of animals undergoes in their glands, before it is changed into the different secretions; and assimilated into the substance of the plant. Thus, both essential and aromatic oils are found in some parts of the same plant; mucilage, resin, tannin, extract, acids and alkalies, and even silica, in other parts; but these various productions cannot be considered as the proper juice: they are secretions formed from it. The proper juice of plants is, therefore, "that changed state of

* *Monthly Mag.* 1798.

"the sap, after it has been exposed to the air, and "light, in the leaf, and is returning from it to "form the different secretions." The organs by which the secretion is performed are probably glands, which we have already endeavoured to prove exist in vegetables; and the secreted fluids themselves are deposited in cells in different parts of the plant, particularly in the bark, and the roots; these parts acquiring different medical virtues, from the matters thus lodged in them.

It is almost as impossible to obtain the proper juice of plants free from sap, as it is to procure the sap free from the proper juice; this, however, in the season in which it can be obtained in most abundance, is not so liable to be diluted or mixed with sap as at other times; and therefore it is in the warmest times in summer, that it ought to be taken for the purpose of examining its properties. Some naturalists have, rather fancifully, drawn a very close analogy between it and the blood of animals. Thus Rafn, with a microscope magnifying 135 times, supposed that he could detect round globules, resembling the red globules of the blood, swimming in a clear fluid, in the juice of Euphorbia *palustris;* and Fontana thought he observed them in the sap of Rhus *toxicodendron.* But such observations, which are often the effect of optical deception, are of little value, even admitting their validity, in a physiological point of view. In an

accurate examination of the proper juice of plants, Mons. Chaptal found that in no two kinds of plants does it agree as far as its sensible qualities are considered; but as it is in the leaf that the change from sap into the proper juice occurs, so its sensible qualities are modified according to the action which takes place in that organ; and that this should differ is not surprising if we consider the great difference of the structure of leaves. In one particular, however, Chaptal found that all the specimens he examined agreed. When he poured into them oxygenated muriatic acid, a very considerable white precipitate fell down; which had the appearance of fine starch, when washed and dried, and did not change when kept for a length of time. It was insoluble in water, and was not affected by alkalies. Two thirds of it were dissolved in heated alcohol; and these were evidently resinous, as they were again precipitated from the spiritous solvent by water. The third part, which continued insoluble in both alcohol and water, was found by Chaptal to possess all the properties of the ligneous fibre. In the seed lobes a greater quantity of this woody fibre was found than in the proper juice of the plant itself; a fact which accounts for the rapid growth and increase of parts of the young plant, before the roots are able to take up from the earth the principles of nutriment. The proper juices of plants, both in the seed, and

in the perfected plant, contain nourishment already properly adapted to be immediately assimilated into the substance of the plant. But this preparation takes place, either during the time, or after, the sap has been exposed to the action of the light and air in the leaf; as no woody fibre is found in the ascending sap, although the principles of it are undoubtedly contained in that fluid. A new chemical combination of these principles takes place; but how this is effected, or by what means the change is produced, we know not; and it is one of those mysteries of nature from which human ingenuity will never perhaps be able to remove the veil. In the same manner the blood of animals contains the components of the muscular fibres already formed; and an assimilation of it is constantly going on, without our being able to perceive it, or even to form the most distant conception of the manner in which it is performed.

The elementary principles of the proper juice of plants and of the sap are the same; but differ in the relative proportions. These principles are carbon, hydrogen, and oxygen. The same principles, differently modified, form all the secretions and the solid materials of the plant itself. The extraneous ingredients which some plants are found to contain, as part of their substance, such as the alkaline and neutral salts, metallic oxyds, silex and other earths, are probably obtained ready

formed in the soil, in a state of division sufficiently minute to be suspended in water, and drunk in by the absorbent vessels of the roots. This is in some degree proved by the effect of change of situation on plants which naturally grow near the sea. Most of these plants, when burned, yield soda; but, when they are removed from the sea-shore, and cultivated in an inland situation, potash instead of soda is procured from their ashes.

As the sap undergoes the same exposure to the air and light in all plants, and one product only can be formed in each plant by this exposure, the difference of the proper juice in different plants, is a strong argument in favour of the existence of vegetable glands, independent of the undeniable proof afforded by the formation of the very different products, which are deposited in different parts of the same plant. Unless there were glandular organs, one product only could be produced in each plant by the function of the leaves, and the action of light and of air on the sap. The secretions of plants formed from the proper juice are very numerous, and known under the names of *gum*, *fecula* or *starch*, *sugar*, *gluten*, *albumen*, *gelatin*, *caoutchouc*, *wax*, *fixed oil*, *volatile oil*, *camphor*, *resin*, *gum resin*, *balsam*, *extract*, *tannin*, *acids*, *aroma*, the *bitter*, the *acrid* and the *narcotic principles*, and *ligneous fibre*. These are found in different parts of plants without any uni-

formity of distribution; and although so numerous and different from each other in their sensible qualities and chemical properties, yet are they all composed of different modifications of the same principles, carbon, hydrogen, and oxygen. Thus 100 parts of *gum*, according to the experiments of Gay Lussac and Thenard *, consist of

| | |
|---|---|
| 42.23 | of carbon, |
| 6.93 | of hydrogen, and |
| 50.84 | of oxygen, the oxygen and hydrogen being nearly in the same relative proportions as they are contained in water. |
| 100.00 | |

100 parts of common *resin* consist of

| | |
|---|---|
| 75.944 | of carbon, |
| 15.156 | of a combination of oxygen and hydrogen in the same proportions as they exist in water, and |
| 8.900 | of hydrogen in excess. |
| 100. | |

100 parts of *olive oil* consist of

| | |
|---|---|
| 77.213 | of carbon, |
| 10.712 | oxygen and hydrogen, as in water, and |
| 12.075 | of hydrogen in excess. |
| 100. | |

* *Recherches physico-chimiques*, t. ii. p. 290.

The solids, also, except the earths and salts, are formed from the same principles: 100 parts of the ligneous fibre of the Beech and the Oak, for example, consisting of

| | Beech. | Oak. |
|---|---|---|
| Carbon | 51.45 . . . . . | 52.53 |
| Oxygen | 42.73 . . . . . | 41.78 |
| Hydrogen | 5.82 . . . . . | 5.69 |
| | 100.00 | 100.00 * |

and thus almost the whole of vegetable matter may be resolved into these three simple elements.

Such are the general components of vegetables. The investigation of them is yet in its commencement only, and much must be done before their real properties be fully understood. It is requisite that the student keep them constantly in view, for otherwise much of the more detailed part of our subject will appear obscure and confused.

* *Recherches physico-chimiques*, t. ii. p. 294. *Thomson's Chemistry*, fifth edition, vol. iv. p. 183.

## LECTURE IV.

VEGETABLE ORGANIZATION.—THE ROOT—ITS SITUATION, SPECIES, AND VARIETIES—DIRECTION AND DURATION.

Having endeavoured to give you some idea of the general components of the vegetable body, I have now to describe to you the organs formed by the combination of these constituents.

Every plant, as I have already stated, possesses two sets of organs. One of these is intended merely for the growth and preservation of the individual; the other for the propagation, and, consequently, the continuation of the species:—or all plants are endowed with CONSERVATIVE and REPRODUCTIVE organs.

If we dig up a tree or a shrub in the summer, when it is in flower, and some of the fruit is already formed, an Orange-tree for example, which bears flowers and fruit at the same time, we have, in one plant, a complete display of these parts. In the first set are comprehended the *root*, the *trunk*, the *branches*, and the *leaves*, with their appendages; in the second, the *flower* and the *fruit*, with their appendages. Many phytologists regard those species of plants only, which possess

all, or the greater part of these organs, as perfect; and those in which some of the more conspicuous of either kind are not present, or are apparently deficient, as imperfect. But we need not hesitate in pronouncing this opinion erroneous; for, as the perfection of a plant consists in the power of its organs to carry on its functions, and to continue the species, individuals only can be imperfect.

The different organs, in whatever manner they are present, assume a considerable variety of form; and as it is on that variation that Botanists have founded specific distinctions; and as it is of importance in a physiological point of view also, the student ought to make himself well acquainted with the distinguishing characteristics which it constitutes. In examining these, the best method is to take the organs in the order in which they have been enumerated: let us, therefore, commence with the CONSERVATIVE.

*a.* The ROOT *(Radix)* is defined by Linnæus to be that part of a plant which imbibes its nutriment, producing the herbaceous part and the fructification; and which consists of a *caudex*, or body, and *radicles* *. Simple as this definition appears to be, it is, nevertheless, objectionable, inas-

* "Radix alimentum hauriens, herbamque cum fructifica-" tione producens, componitur medulla, libro, cortice; constat-" que *caudice* et *radicula*." *Phil. Botanica.*

much as many succulent plants in arid situations do not receive their nutriment by the root; nor is the root the nutritious organ in the tribes named Hepaticæ *, Confervæ †, and Fuci §; in all of which it can be regarded as an attaching organ only, designed to secure the individual to the soil, or to the substance on which it is fixed. A less exceptionable definition is that adopted by Mr. Keith, which characterizes the root as "that part "of the plant by which it attaches itself to the soil "in which it grows, or to the substance on which "it feeds, and is the principal organ of nutrition ||." It might be stated, as an objection to this definition, that plants exist which have roots, and, yet, are not fixed by them either to the soil or to any other substance; as for example, Duckweed (Lemna), a small green lenticular plant, which floats abundantly on the surface of our stagnant pools in summer, and has unattached roots which hang perpendicularly loose in the water. But all plants are at first attached; and as it is impossible to frame any definition to which no exception

* A tribe of small herbaceous plants resembling the Mosses found in damp shaded places.

† An aquatic genus, consisting of fibrous, or threadlike jointed and branched parts, closely matted together.

§ Marine plants of various forms attached to rocks and stones.

|| *System of physiological Botany*, vol. i. p. 33.

could be advanced, this "is perhaps," as Mr. Keith remarks, "as comprehensive as any one "that can be given."

In all plants the primary root is a simple elongation of that part which, during the germination of the seed, is first protruded, and is denominated the radicle; but as the plant continues to grow, the root gradually assumes a determinate form and structure, which differs materially in different plants, but is found always similar in all the individuals of the same species. Botanists have taken advantage of this fact, and have classed roots according to their forms, as seen in the adult, or fully grown root; and have availed themselves of these diversities for fixing specific distinctions. The classification of roots, which I have ventured to arrange, differs from that which is usually found in works on the elements of Botany; but it is one which, I trust, will enable you to form accurate ideas regarding the structure and functions of these important organs. Before, however, entering upon the consideration of it, you ought to be informed that every root, whatever may be its form, consists of two distinct parts, the body, *caudex*, and the rootlet, *radicula*. The main part of the root, caudex *, in trees and plants that

* "Caudex descendens sub terra sensim subducit, et radicu-"las profert, a Botanicis ex varia structura variis nominibus "distinctus." *Phil. Bot.* § 80.

live for several years, is in general woody, and is to the other parts what the trunk or stem is to the branches and leaves; enlarging progressively in a similar manner, and giving off lateral branching shoots, which spread horizontally, or in a direction that forms nearly a right angle with the caudex. In those plants, however, the herbaceous part of which dies annually whilst the root survives, and in many annuals, the caudex is also a reservoir of nutriment, which is intended for the renewal of the herbaceous part in the following season, or to be expended in perfecting the flower and the seed. The rootlets, *radiculæ* *, are small, or threadlike productions of the caudex, terminating in *fibrils*, which are extremely minute, the real absorbing organs of the root; and are supposed by Du Hamel †, Willdenow ‡, Sir E. J. Smith § and others, to die annually in the autumn with the foliage, and to be reproduced in the spring; an opinion which Mr. Knight ‖ regards as incorrect, as far at least as concerns the terminal fibres of woody plants. My own ex-

* "*Radicula* est pars radicis fibrosa, in quam terminatur "caudex descendens, et qua radix nutrimentum haurit pro "vegetabilis sustentatione." *Phil. Bot.* § 80.

† *Phys. des Arb.* liv. i. chap. v.

‡ *Principles of Botany*, § 11.

§ *Introduction to physical and systematical Botany*, p. 104.

‖ *Phil. Trans.* 1809.

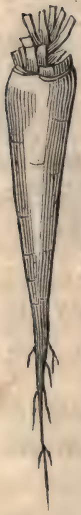
perience and observations, however, lead me to believe that, even in woody plants, the fibrils are annual productions.

Every root may be arranged under one of the three following classes, i. Simple Roots; ii. Branched Roots; iii. Articulated Roots.

i. The Simple Root consists either of a single caudex furnished with fibrils only, or of one or more rootlets with fibrils*. Considered as a genus, it comprehends three species, the *conical*, the *subglobular*, and the *fibrous*.

1. The *Conical* root *(Radix conica)* (fig. *a*) is a tapering caudex furnished with lateral fibrils, which are situated chiefly towards its smaller extremity. It is generally a reservoir of nutritious matter which is prepared in the leaves, and is the proper juice of the plant, to be exhausted in the production of the flower and the seed. The change which takes place at the flowering season in culinary roots of this description, as for example, in the Carrot, is rendered very evident; by the nutritious matter it contains becoming less saccharine, diminishing in quantity, and the whole root acquiring a woody consistence. The wedgelike form of the conical root seems to

*a.*



* "*Simplex* quæ non subdividitur." *Phil. Bot.* § 80. b. 3.

be particularly well adapted for penetrating perpendicularly into the ground; but that this is not the sole intention of nature in giving it this form would appear from the fact, that the direction of some conical roots is horizontal; as, for example, the Blood Root, Sanguinaria *Canadensis**, a North American plant, which is conical, truncated, and horizontal; the root forming a right angle nearly with the stem. The roots of the Carrot, Daucus *carota;* the Parsnip, Pastinaca *sativa;* the Horseradish, Cochlearia *Armoracia;* and the Dandelion, Leontodon *Taraxacum;* are familiar examples of the conical root. The following may be regarded as its varieties.

*b.*

*a.* The Spindle-shaped root *(Radix fusiformis*†) (fig. *b*) differs from the real conical root only, in not tapering equally throughout its length, but swelling out a little below its summit, like the spindle or wooden pin employed by ancient matrons in forming the thread, which they drew from the flax wrapped round the distaff; whence its name. Like the proper conical root, it is a reservoir of nu-

* *Vegetable Mat. Med. of the United States*, p. 31.

† "*Fusiformis* quæ oblonga, crassa, attenuata: ut *Daucus*, "*Pastinaca*." *Phil. Bot.* § 80. This is the definition rather of the conical root than of the spindle-shaped.

tritious secreted matter; and by its shape, it is well calculated to penetrate the ground. The Radish, Raphanus *sativus;* and the Beet, Beta *vulgaris;* are the best examples of this form of root.

*b.* The Abrupt or truncated root (*Radix*

c.

*præmorsa* *) (fig. *c*) is originally an entire conical root; but after some time the lower extremity decays and drops, as if it had been bitten off, while numerous lateral rootlets are protruded from the remaining portion. Such is the case in the root of the larger Plantain, Plantago *major*, and in that of Scabiosa succisa, which, according to Gerarde †, received its common appellation Devil's Bite, *Morsus Diaboli* (fig. *c*), from a superstitious opinion connected with this appearance of the root.

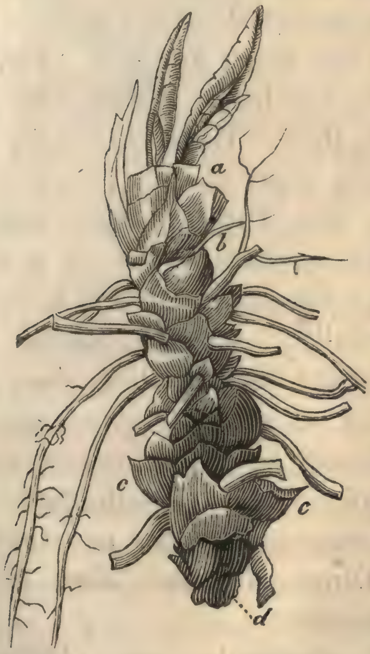
A curious modification of the Abrupt root

* "*Præmorsa*, quæ deorsum truncata est, nec attenuato "apice terminatur; ut *Scabiosa, Plantago, Valeriana.*" *Phil. Bot.* § 80. 9.

† The old herbalist's words are, "The greater part of the "root seemeth to be bitten away: old fantasticke charmers re-"port, that the devil did bite it for envie, because it is an herbe "that hath so many good vertues, and is so beneficial to man-"kinde." Vide Herbal, p. 726.

which occurs in a few herbaceous plants, and which has misled some Botanists to describe it erroneously in these instances, as an articulated or scaly jointed root, depends on the following circumstance, which was first noticed and described by Dr. Grew*. In the Primrose, Primula *veris*, for example, the root is abrupt; but as the lower leaves of the plant annually decay and fall, they leave a small portion of their basis at the place of their attachment, which swells and becomes more succulent; and the plant sinking in the ground, lateral fibres are protruded above each of these portions; so that the buried part of the root, owing to a similar decay and sinking annually taking place, gradually assumes the character of a long caudex, and the whole bears a strong resemblance to a notched or articulated root. See (fig. *d.*) *a*, the present year's

*d.*




* *Anatomy of Plants.*

foliage; *b.* the remains of last year's, with a rootlet protruded above it; *c. c.* bases of old leaves converted into firm toothlike scales or processes; *d.* the decayed, or truncated root. The cause of this decay of the lower extremity of some conical roots shall be explained, when treating of the physiology of these organs.

2. The *Subglobular* root *(Radix subrotunda)* is an almost spherical caudex, terminating in one or more small tapering points. Like the conical root, it is a reservoir of nutritious matter intended for the production of the flower and seed. The best example of it is the black Radish, Raphanus *sativus*, var. B. niger. There are two varieties of the subglobular root:

*e.*

*a.* The Turnip-shaped root *(Radix napiformis)* (fig. *e*) is a caudex, the shape of which is the intermediate of the spindle-shaped and the subglobular roots, bellying out suddenly above, and terminating below in a long tapering point furnished with fibrils. It is scarcely necessary to quote the Turnip, Brassica *Rapa*, as an example.

*b.* The Flattened subglobular root *(Radix placentiformis)* has the appearance of a globular caudex which is compressed both above and be-

low. It has not the tapering point of the two former, but a number of long fibrils which hang from the centre of the lower depression. The Sow-bread, Cyclamen *europœum* (fig. *f*), which

*f*.

is an example of this root, does not attain its decisive character in the first year of its growth; and although a reservoir of nutriment, yet it is not exhausted in perfecting the flower and fruit, but continues to increase for several years.

The nutriment which is deposited in the caudices of all these species of the simple root, is not that which is directly absorbed from the soil by the fibrils; but the proper juice of the plant, prepared from the sap exposed to the action of the light and air in the leaves. The necessity of a luxuriant and healthy state of the herbaceous part of the plant, therefore, for increasing the quantity of nutritious matter in the simple roots, which are cultivated for food, is very obvious. It may be thought that the practice pursued to produce earlier and larger Radishes, "which is by sowing them in "hot-beds in the early spring, and exposing the "tops to the cold air during the day, as this pre-"vents the luxuriant growth of the summit, and

"increases that of the root*," militates against this opinion: but it may be answered, that by exposing the tops to the cold air, whilst the fibrils of the roots are in a state of activity, the functions of the leaves are not altogether suspended; and the only difference produced by the diminished temperature moderating their action, is, that less of the watery part of the sap being thrown off during its exposure in the leaves, the proper juice is consequently more abundant because it contains more water. It is still, however, proper juice, and is conveyed from the leaves into the caudex, which is necessarily enlarged; but it is less perfectly formed, and the root as an article of food wants its proper flavour.

That the fibrils are the principal absorbing parts of the roots we have just examined, is evident; for, by merely placing the extremity or tapering point of a Turnip covered with its fibrils in water, the herbaceous part continues to grow and put forth fresh leaves, which does not happen if the caudex only be surrounded with water, and the point kept dry. It is owing to this circumstance, also, that Turnips and similar roots thrive and enlarge, although nearly the whole of the caudex be above the surface of the ground.

3. The *Fibrous* root *(Radix fibrosa)* consists of rootlets only, which convey the nutriment ab-

* *Darwin's Phytologia*, sect. xvii. 1.

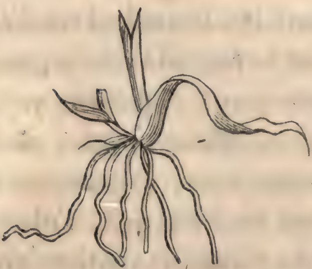
sorbed by their fibrils directly to the basis of the stem and leaves, or into what is termed a bulb. Besides the *bulb*, which has a close analogy to buds, all plants, also, that have those underground organs for reproducing or rather continuing the species, which have been named *tubers*, have fibrous roots; and although Linnæus has fallen into the error as far as regards the tuber-bearing roots *, and the mistake concerning both them and bulbs continues to be repeated in Botanical works, yet, it is not the less incorrect to regard these organs as roots, which, as I shall afterwards explain to you, are merely appendages to some fibrous roots; and thence the terms Bulbiferous root, Tuberiferous root, should be substituted for Bulbous root, Tuberous root. In the bulbiferous roots the rootlets are attached to the basis of the bulb, either directly or by the intervention of a radicle plate †; in the tuberiferous they proceed from the basis of the

* Linnæus defines them thus: " *Tuberosa* (radix) quæ sub-" rotundis constat corporibus in fasciculum collectis; *Pæonia*, " *Hemerocallis, Helianthus, Solanum, Filipendula.*" *Phil. Bot.* § 80. 6.

† The term Bulbiferous root has already been adopted by Mirbel, who thus defines it; " Nous devons entendre par ra-" cines bulbifères, des tubercules minces, élargis en plateau dont " la surface inférieure produit des filets radicaux, et dont la " surface supérieure porte un ognon, ou *bulbe*." *Elem. de Phys. végét.* t. i. p. 91.

stem or the herbaceous part of the plant, and are generally above the tubers, to which they are not attached. It is necessary to remark that, in some instances, both in the bulb and the tuber-bearing roots, the rootlets are unsupplied with fibrils, performing themselves the functions of these organs; and, like them, they annually decay with the foliage in the autumn, to be renewed with it in the spring. The majority of annual plants and many Grasses, as, for example, the Sea Canary Grass, Phalaris *arenaria* (fig. *g*), have fibrous roots. The following are varieties of the fibrous root.

*g.*



*a.* The *Filiform* root *(Radix filiformis)* is composed of distinct and separate threadlike rootlets, as in Duckweed, *Lemna*.

*b.* The *Capillary* root *(Radix capillaris)* (fig. *h*) consists of many very fine fibres, as in Sheep's Fescue-grass, Festuca *ovina*, and many other Grasses. You will find, in works on Elementary Botany, the Tufted root *(R. comosa)* described as a modification of the Capillary root; but it is, correctly speaking,

*h.*

not a fibrous root, the hairlike tufts of which it consists being attached to a caudex which fixes the character of the root. The male Fern, Aspidium *Filix mas*, affords a good example of the tufted or cespitose root.

*c.* The *Funiliform* or cordlike root *(Radix funiliformis)* is formed of thick fibres resembling cords more or less fine, generally simple, but sometimes slightly ramified. In the Palms which have roots of this description, the cords are very strong and diverging, so as to take a firm hold of the ground and maintain the perpendicularity of the plant, a circumstance of great importance to this tribe of vegetables, many of which are simple columns rising more than a hundred feet in height, and bearing the whole weight of their magnificent foliage at the summit. The succulent plants of tropical climates also, which obtain the greater part of their support by the absorbing organs of the leaves and stems attracting the moisture of the atmosphere, have funiliform roots, the chief use of which is to rivet them down to the soil, and secure their stability.

ii. The Branched root *(Radix ramosa)* consists of a caudex or main root, divided into lateral branches*, which are again subdivided and ulti-

* "*Ramosa* quæ in laterales ramos dividitur." *Phil. Bot.* § 80.

mately terminate in absorbing fibrils; so that the

i.

root in its divisions resembles the stem and branches inverted (fig. *i*). This form of root is the most general being that of all trees and shrubs, and also of many herbaceous plants; for example, Elecampane, Inula *Helenium*, and Seneka, Polygala *senega*. The following are the only species:

1. The *Branched* root *(Radix ramosa)*, as described under the genus.

2. The *Toothed* root *(Radix dentata)* (fig. *k*),

k.

which is a fleshy caudex with short branches and teethlike prolongations, as in Ophrys *corallorhiza*.

iii. The *Articulated* or *Jointed* root *(Radix articulata)* is apparently formed of distinct pieces united, as if one piece grew out of another, so as

to form a connected whole, with rootlets proceeding from each joint. The articulations are in some instances kneed; in others they resemble nodules or beads.

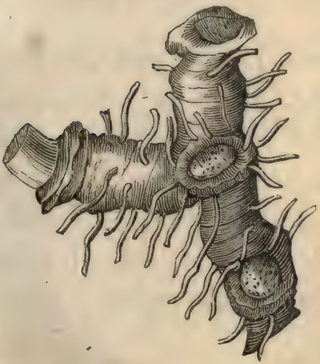
The following may be considered species of the jointed root:

1. The *Simple Articulated* root, when the pieces of which it is composed are attached longitudinally, or nearly so, as in Wild Ginger, Asarum *Canadense* (fig. *l*).

*l.*

2. The *Kneed* root *(Radix geniculata)* has some of the articulations forming a knee; as in Hedge Hyssop, Gratiola *officinalis;* and Solomon's Seal, Convallaria *polygonatum* (fig. *l**), which is, besides, a bulbiferous root, and truncated in such a peculiar manner at the points of detachment of the annual stems, as to have given rise to its vulgar name;

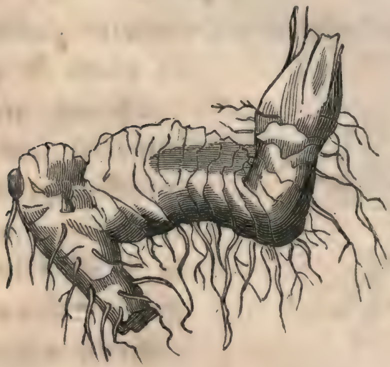
*l*.*



the cicatrizations bearing a fancied resemblance to impressions of a seal.

*a.* The *Contorted* root *(Radix contorta)*, although it cannot strictly be regarded as an articulated root, yet, it may be classed with propriety as a modification or variety of the kneed root. The Bistort, *Polygonum Bistorta* (fig. *m*), affords the best example of it, the name of the plant having originated in the double turn which the root takes. The caudex of the root, which is perennial, is a reservoir of nutriment for the annual renewal of the herbage.

*m.*



3. The *Necklace-like* root *(Radix moniliformis)* (fig. *n*) is an articulated root with nodular joints, united together so as to resemble beads in a necklace ; as in Tall Meadow Oat, Avena *elatior nodosa.*

*n.*

Such are the general forms of roots, and the

names by which they are known to Botanists; and under one or other of these species, with very few exceptions, every variety of root may be classed. One exception only is necessary to be particularly noticed as it refers to a root, which is frequently improperly quoted by elementary authors as an example of a root bearing pendulous tubers like the Potatoe; although, in fact, it is merely a conical root with thick lateral rootlets swelled, near the extremity of each, into a solid nodule. This form of root is the *Radix filipendula* of authors; as exemplified in the root of Common Dropwort, Spirea *filipendula* (fig. *o*), which is in strict

*o.*

language a nodose root, the tubers or knobs being perennial, actually parts of the root, and reservoirs of nutriment for the use of the plant itself, pro-

bably, as has been suggested, to enable it to resist drought; and not at all resembling the tubers of the Potatoe and other similar tuberiferous roots, which are annual productions; and, as I shall presently explain to you, belong nearly as much to the stem as to the root.

Having finished the observations I had to offer on the external characters of roots, our next object is to examine the APPENDAGES of these organs; which are as fixed in their forms as the roots themselves, and are, consequently, taken advantage of in describing plants. All the appendages of roots may be arranged under the following genera:—1. *Scales*; 2. *Suckers*; 3. *Knobs* or *Tubers*; and 5. *Bulbs*.

1. SCALES are in many instances the remnants of leaves which have decayed and fallen, as has already been explained (p. 133). They more frequently occur in roots which assume a horizontal direction; in which cases the lower part of the stem which is in contact, or nearly so, with the soil, gives off lateral rootlets, immediately above the point of attachment of the decayed leaf; and these, dipping into the ground, drag that portion of the stem under the surface of the earth, where it gradually acquires all the characteristics of a root. There are, nevertheless, some roots originally furnished with scales, and very few or no lateral

rootlets, as in Toothwort (Lathræa *squamaria)*

p.

(fig. *p*); and it is not improbable that the scales, which are generally fleshy, are reservoirs of nutriment for the use of the plant.

2. The Sucker *(Stolo)* is an underground bud protruded from the upper horizontal branches of the roots of trees, or those nearest to the surface of the soil; and which, ascending above the earth, is converted into a stem, resembling the parent tree; as exemplified in the common Lilac (Syringa *vulgaris)*, the Elm, and many other trees, particularly fruit-trees, round the stems of which, young plants of the same species as the stock are seen constantly rising; and also in some herbaceous plants. The sucker, in its earlier state, has the closest resemblance to the leaf-bud; and in its more forward growth to the branch, protruded from the part of the plant which is above ground; circumstances which prove the affinity of the stem and the root. It never detaches itself spontaneously from the plant, but, if artificially separated along with a small portion of the root, it may be transplanted, and will grow, constituting a distinct vegetable being; although differing essentially, as I shall afterwards have an opportunity of explaining to you, from

the young plant which is the seminal production of the same parent. Whilst the sucker is attached to the root on which it is formed, it derives its nourishment through the same organs that supply the principal stem, which, consequently, must become impoverished in proportion to the number of suckers that surround it.

3. The KNOB OR TUBER (*Tuber*) is a solid fleshy body, attached to many fibrous-rooted plants, either immediately at the basis of the stem under the rootlets, or mediately by means of cords or wires which proceed from the basis of the stem. The tuber itself is not furnished with any rootlets or fibrils; which circumstance distinguishes it from nodular and globular roots, with which it is frequently confounded in the description of plants. It is composed of cellular substance filled with a moist, amylaceous fecula; is covered with a cutis vera and epidermis; and furnished with vessels, which are collected at one point or at different points on the surface, where a bud or gem and rootlets are protruded when the tuber has attained its full maturity, and is placed in a situation favourable to vegetation*. It is, in fact, a reservoir of nutriment

* Mirbel thus describes tubers: "Les tubercules, qui ont "fait donner le nom de tubéreuse à certaines racines, sont des "renflemens charnus, souvent arrondis, masses de tissu cellulaire, "que parcourent quelques vaisseaux qui se rendent vers tous les "points de la surface, d'où doivent partir les filets radicaux et "les turions. Les poches du tissu cellulaire des tubercles sont

intended to support these buds during their evolution and the earlier stage of their growth as plants; and thence tuberiferous plants, which are chiefly annuals, are perpetuated both by a lateral and seminal progeny. In this respect the buds produced on tubers resemble suckers; differing from them only in not being dependent on the original root for their nutriment, but obtaining it from the tuber; and in separating spontaneously from the parent plant, and becoming distinct, isolated beings. They resemble seeds also, inasmuch as the gems upon their surfaces are endowed with vitality, like the embryon or plantule enclosed in the seed, and remains latent, until the tuber be placed under circumstances favourable for vegetation.

Tubers are annual productions of the herbaceous part of the plant; both the nutritious fecula deposited within them, and the gems on their surfaces, being formed from the descending or proper juice, which, as you already know, is the sap, or fluids taken up by the roots, changed by exposure to the action of the air and the light in the leaf. They are, in strict language, rather appendages of the stem than of the root*; and are con-

"remplies d'une fécule amilacée." *Elémens de Phys. vég.* t. i. p. 90.

* The following description by Dr. Darwin, of a variety of the Potatoe raised in the garden of Major Trowel of Derby, is a good illustration of this remark: "From one root there "appeared to issue six or eight stems, three or four feet long,

sidered as belonging to the latter merely from the circumstance of their being underground productions. The older phytologists regarded them as roots; and we may still speak of them, without much impropriety, as appendages to these organs, if we obtain, in other respects, a correct idea of their nature and functions. They assume a great diversity of forms, which, as they frequently enter into botanical descriptions, ought to be made familiar to the student. In describing them I shall arrange the whole under two genera: *a.* Closely attached tubers; *b.* Filipendulous tubers.

*a.* Closely attached tubers are seated directly at the basis of the stem, or rather adhere to it*, and grow in immediate contact with each

" at every joint of which were produced new Potatoes; at the " lower joints there were three of these aërial Potatoes, one " large, one the size of a pullet's egg, and a smaller one on each " side of it. At the upper joints only one new aërial Potatoe " adhered, and these became smaller the further they were " removed from the root; and, finally, at the summit there " had been a flower, as there was now a seed-vessel, called a " Potatoe-apple. All these new Potatoes at the joints of the " stems were green, because they had not been etiolated by " being secluded from the light, but the terrestrial roots " (tubers) were white." *Darwin's Phytologia*, sect. xvii. 1, 2.

* This place at the basis of the stem to which these tubers usually adhere is marked by a little contraction or sometimes protuberance, which the French botanists call *le collet*, the collar. " On donne aussi le nom de *collet* à une espèce d'étranglement " ou de rebord, qui sépare une tige d'avec sa racine." *Dict. élément. de Bot. par Bulliard.*

other. They comprehend the following species, regarding them as appendages of the root:

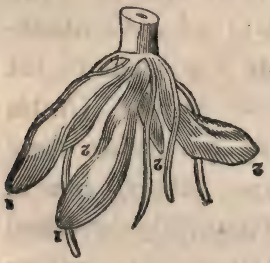
1. The *Conjoined ovate* tuber *(Tuber conjunctum ovatum)* is an egg-shaped tuber, in immediate contact with another, and more rarely a third, at

q.


the point of its attachment to the stem of the plant, as in the Orchis tribe (fig. *q*). When there are three tubers, one of them is generally shrivelled almost to a skin, another a little less so, and the third quite plump: and when there are two only, one is always somewhat shrivelled, if the root be examined after the plant has flowered. The full tuber is the formation of the present year, and bears on it a gem for the production of the plant of the following year; but the shrivelled one is that of the preceding year, which having its nutritious contents exhausted in formation of the herb and the flowers, shrivels towards autumn; and either withers away altogether and disappears in the succeeding winter, or remains a mere skeleton in the third year. The ovate conjoined tuber is therefore biennial, being formed and perfected in one year, and performing its functions and dying in the second. In fig. *q* are seen these three states of tuber as displayed in Orchis *acuminatum:*

1. shows the tuber nearly shrivelled to a skin; 2. the tuber of last year after the plant it bears has flowered; 3. the new tuber, the production of the present year; 4. are the real roots of the plant*.

*r.*




Our conjoined ovate tuber is the *Radix testiculata* of authors†.

2. The *Conjoined club-shaped* tuber *(Tuber clavæforme conjunctum)* (fig. *r*) is of an oblong shape, thicker at the loose extremity, and resembling in some degree a short club. As in the former species of tuber, it is generated every

* There formerly existed a very absurd superstition connected with the double state of these tubers. If a pair of them be separated and thrown into water, the new tuber, owing to its greater gravity, sinks, whilst the older one, being lighter, swims. The swimming tuber, when prepared in a particular manner and worn round the neck, was believed to possess the magic property of securing to the wearer the strongest attachment of any one he pleased; and this belief still continues to prevail to some extent among the ignorant. A more rational and useful purpose to which the new tuber of the Orchis *morio*, and some other species of the *Orchideæ* is applied, is the manufacture of salop. For this purpose the new tuber, which has attained its perfect growth, is prepared by first scalding it in boiling water to detract the skin, then placing it in an oven for ten or twelve minutes to give it semitransparency, and finally drying it in a moderate heat. In this state it resembles sago, and constitutes a nutritious wholesome article of diet.

† Quasi testiculis animalium similis.

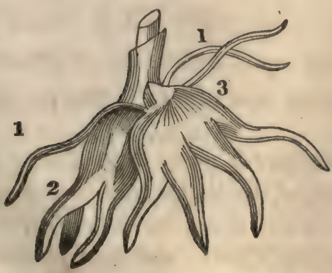
year; but there are always two or more tubers in a state of advancement towards perfection, and as many in that of decay. Pile-wort, Ranunculus *ficaria*, affords the best example of this form of tuber: vide fig. *r*, in which 1. 1. indicates the more recent tubers; 2. 2. those in a state of decay.

3. The *Fingered* tuber *(Tuber digitatum)* (fig. *s*) receives its name from the tubers resembling fingers. In Satyrium *albidum*, the plant exhausts two tubers in one season; see fig. *s*, in which *b. b.* represents a pair of old tubers, the origin of the existing plant; *a.* a pair of tubers for that of the next year, with a still younger pair attached to them: *c. c.* are the real roots of the plant.

*s.*


4. The *Palmated* tuber *(Tuber palmatum)* (fig. *t*) also receives its name from its form, which somewhat resembles the human hand. There are rarely more than two palmated tubers conjoined, as in Orchis

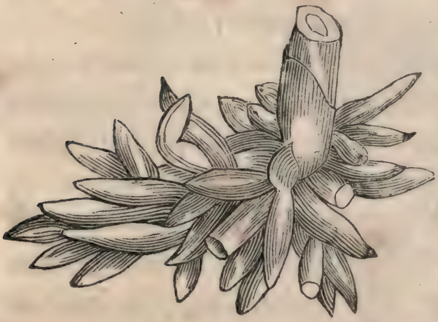
*t.*



*maculata*. In fig. *t*, 1. 1. represents the roots; 2. the withering tuber, the origin of the present plant; 3. the new tuber, the pyramidal elevation on the top of which marks the point, whence shall germinate the plant of the ensuing year.

5. The *Bundled* tuber *(Tuber fasciculatum)* (fig. *u*) is spindle-shaped or nearly cylindrical. Tubers of this description "are "formed, and also "wither away in "parcels," each parcel being equivalent to a single tuber in the species already described: they are well exemplified in Bird's-nest Ophrys, Ophrys *nidus avis* (fig. *u*).

*u.*



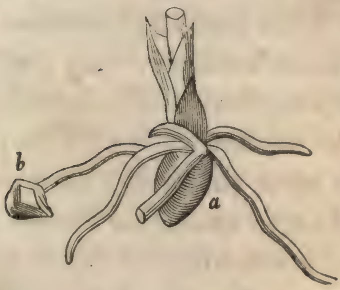
Such are the closely attached tubers. From the circumstance of the new tuber, or the sets of tubers, being always formed laterally to the old, the plant appears to perform a certain degree of progression; so that in a few years it is found at some distance from the spot where it originally flourished*. I have used the term, "the plant,"

* The cultivation of tuberiferous plants with closely attached tubers, which are chiefly of the Orchis tribe, has always been considered very difficult; but it may be successfully managed as practised by the late Mr. Crowe, and thus described

because, although a new plant actually rises every year from the new tuber, or that one in the regular order of succession; yet each is only a continuation of the plant raised from the seed perpetuated by lateral production, as the buds on an ungrafted tree are continuations of the original tree; and differ essentially from the seedling plant, which is a real renewal of the species.

*b*. FILIPENDULOUS TUBERS are attached to the parent plant by underground runners, or cords, which spring not from the roots but the lower part of the stem; the roots being in this instance, as in the plants with closely attached tubers, truly fibrous. There are two species only of the filipendulous tubers; *solitary* and *congregated.*

*v.*




1. The *Solitary* pendulous tuber *(Tuber solitarium)* (fig. *v*) is egg-shaped and attached, as

by Sir J. E. Smith: "They are best removed when in full flower, "the earth being cleared completely away from the roots "(tubers), which are then to be replanted in their natural "soil previously dried and sifted. Afterwards they must be "well watered. The bulb (tuber) for the following year has "not at the flowering period begun to throw out its fibres, for "after that happens it will not bear removal." *Introd. to physiological and systematic Botany*, p. 110.

at *b.* to the extremity of a lateral runner, proceeding from the collar of the stem, immediately above *a.* the old, or plant-bearing tuber. As the new tuber makes very little progress until after the flowering of the parent plant is over, it may escape the observation of the student, if looked for before that period. The Musk Orchis, Ophrys *monorchis* (fig. *v*), which has received its specific name Monorchis *, from having apparently but one tuber, is the only example of this species of tuber with which I am acquainted.

2. *Congregated* pendulous tubers *(Tubera congregata)* are more generally either globular or ovate, surrounding the stem, attached by runners or fibres which connect them with it at different distances, and in indefinite numbers. Like all other tubers, they are reservoirs of nutriment and moisture; whilst the runners to which they are attached perform an office similar to that of the umbilical cord in animals; conveying the proper juice from the parent plant to the tubers, to be deposited in them for the support of the succeeding plants; and maintaining the connexion between the plant and its lateral progeny, the gems on the surface of the tubers, until these are perfected and endued with that vitality which enables them to exist as independent beings. It is a

* From μόνος *(monos)*, one.

conjecture which is not improbable, that the final cause of the length of the runners is to place the tubers at a convenient distance from the parent plant and from each other, in order that the new plants may enjoy the advantages of a fresh and unexhausted soil.

The Potatoe, which affords the best exemplification of this species of tuber, has many gems on its surface, all of which shoot up into stems; and from each, besides the runners for the production of new tubers, rootlets are given off for the absorption of that portion of nutriment which is required to be supplied from the soil for the support of the vegetating plants.

Such are all the species of tubers which I think it necessary to particularize; and to one or other of them, every known tuber may be referred. Other species are undoubtedly noticed by authors, under the head of tuberous roots; but these will be found to be varieties only of some of those we have examined: even the granules attached to the roots of the White Saxifrage, Saxifraga *granulata*, are sometimes quoted* as tubers, although they actually belong to the next of the appendages of the root, which we have to take under consideration, the bulbs. The roots of several species of the Iris tribe have some resem-

* *Keith's Syst. of physiological Botany*, vol. i. p. 39.

blance to the tuber; but although the new caudexes of these roots bear buds, which may be correctly regarded as lateral progeny, yet, these caudexes are nevertheless real roots, and do not accord with the definition of tubers. I shall have to notice them more particularly when we examine the direction of roots.

As in tuberiferous plants, the tuber is formed by the plant of the present year, and itself forms that of the succeeding, which again forms a new tuber or tubers, it becomes a subject of rational inquiry to ascertain the part which the real roots of the plant act, in producing these results. That the plant is sustained to a certain degree by the absorbing powers of the real roots, is obvious; but it has not, yet, been determined to what extent or at what period it might be deprived of the tuber and be supported solely by the roots. In the early stage of its growth it is altogether nourished by the tuber, the nutriment passing directly from the tuber into the vessels of the stem, and ascending through them to nourish the plant. When the roots begin to absorb from the soil, the fluid matters they take in are probably mingled, in the leaf, with the already formed nutriment brought from the tuber; and it is not unlikely that it is from the proper juice produced by the exposure of this mixture to the air and light in the leaf, that the new tubers are formed. That the new tubers, however, may be

formed independent altogether of the nutriment obtained from the tuber bearing the plant, is evident; for, the first tubers of the plant raised from seed are formed altogether from the nutriment obtained from the soil. It should, however, be recollected, that the plant raised from seed differs from that evolved from the gem on a tuber; the former being an entire new being, a renewal of the species, the latter a mere continuation of the individual from which it springs. It may be supposed, that although the new tubers be formed from the nutriment obtained from the soil, yet that the contents of the old tuber are intended chiefly for perfecting the flower and the seed *, in the same manner as the saccharine matter deposited in the caudexes of the Turnip and Carrot; but, admitting this supposition, it is not the less true that this nutriment may be diverted to the use of the new tubers; for those on the Potatoe plant, are both enlarged and multiplied by nipping off the flowers, to prevent the formation of the seed. From whatever source the nutriment is obtained, the healthy state of the leaf is absolutely requisite to perfect the tuber; for, the partial destruction of

* This supposition certainly obtains some support from the fact, that Potatoes produced on plants raised from seed do not flower in the second or third year; the tubers apparently requiring a greater magnitude and higher degree of perfection before they can form the flower.

these by insects or frost, or the impeding of their functions by disease, as for example the curling of the leaves of the Potatoe plant, is followed by a decrease both in the quantity and in the size of the new tubers, and also by a deterioration of the nutriment deposited in them.

The runners to which pendulous tubers are attached are bundles of vessels, produced from the bark of the stem, and intended solely to convey the proper juice from the descending vessels to these knobs; and that there are no returning vessels, or, in other words, that the progression of fluids through these runners is in a direction from the stem to the tubers only, is rendered probable from the following experiment made by Mr. Knight. He divided the runners connecting the tubers with the stem in a Potatoe plant, and immersed both portions in a decoction of Logwood. The colouring matter passed along in both directions, but did not enter the stem, which it would have done had there been any returning vessels in the runners, whilst it was found to have entered the tubers and filled an elaborate assemblage of vessels which are situated between the bark and fleshy parenchyma *.

The anatomy of tubers displays a considerable difference in the structure of those which belong

* *Phil. Transactions*, 1803.

to the tribe of plants named *Monocotyledons* and that denominated *Dicotyledons;* it demonstrates also, that the organization of the tuber has the closest affinity to that of the stems of the tribe to which it belongs. Thus, for example, the stem of the Orchis *mascula,* which is an annual, tuberiferous, monocotyledonous plant, consists of a lax cellular texture enclosed in a cutis vera and epidermis, with threadlike bundles of vessels running longitudinally through it, at equal distances. The same appearance is evident in the tuber, the vascular bundles or cords being larger only, and inosculating with each other at the lower extremity of the tuber, whilst at the upper they pass into a transverse bundle, which seems to unite with one cord of vessels descending from the stem of the plant, and two cords which apparently connect the vascular system of the new tuber with that of the parent stem and the old tuber. This organization is quite obvious to the naked eye in the half-decayed tuber, and can be made so in the new tuber if the stem of the plant be cut transversely through about an inch from the tubers, and the portion to which they are attached inverted, and allowed to remain for twenty-four hours in a decoction of Brazil wood. When the vessels are thus filled with colouring matter, a longitudinal section of the new tuber displays the vessels running in cords through the cellular texture, which is now swelled with nutritious fluids (vide plate 1. fig. 1. *a*), whilst a transverse

section shows them like coloured points, set in a diamond form, in the white parenchyma (Ib. fig. 2). In the old tuber this appearance varies; the longitudinal section showing the cords of vessels surrounded with the cells still turgid with fluids to a certain distance on every side, and these enclosed as it were with a wall of empty cells, which in a transverse section assumes a circular or irregular hexagonal figure; or each cord of vessels appears as a point in the centre of a large circle or hexagon, the interior of which consists of moist cellular matter, and the walls of dry or empty cells (Ib. fig. 3). This appearance of the old tuber can be explained only on the supposition that during the exhaustion of the nutritious matter it contains, the fluids pass laterally through the cells towards each cord of vessels, by which they are taken up and conveyed to the vessels of the stem and those of the new tuber; and consequently, the more distant cells being those soonest emptied, and each cord of vessels acting as the attractive centre of a given space, the cells on the periphery of each space, owing to the positions of the vascular cords, must necessarily be emptied in such a manner as to give the circular or hexagonal appearance to the transverse section. If this opinion be well founded, it would appear, that the vessels of the tubers of monocotyledonous plants, which during the growth of the tuber convey to and

deposite the nutritious fluids in the cells of the parenchyma, take on a retrograde movement, and acquire the functions of absorbents as soon as the tuber begins to vegetate. A knowledge of the distribution of the vascular system of these tubers, and of the manner in which the new tuber is attached, with the appearance of the embryon plant at its apex, can be readily obtained by examining a longitudinal section of the base of any Orchis, after the new tuber is formed; particularly if the plant be injected with a coloured fluid, as has been already described *. From such an examination it is evident, that, however close the attachment of the new and old tubers is in the closely attached tubers, the attaching organ performs a function very similar to that of the umbilical cord of animals; and resembles in every respect, except in length, the runners which connect the pendulous

* Vide Plate 1. fig. 1. which represents a longitudinal slice of the tuber of the male Orchis, Orchis *mascula*: *a.* the new tuber with its longitudinal vessels, and the intermediate cellular texture turgid with nutritious fluid; *b.* the old tuber in a half-exhausted state; *c.* the stem of the plant broken short; *d.* the plantule, which will form the next year's plant; *e.* a kind of sheath over the plantule, which terminates in a membranous cone, and appears to be formed of a doubling of the cuticle of the stem, reflected so as to unite with that of the new tuber; *f.* the point of conjunction of the vessels of the stem and of the old tuber, with those of the plantule and the new tuber; *g.* a root produced from the stem.

tubers with the parent plant. In fact, the attachment, when the tuber is viewed in its natural state, appears much shorter than it actually is, owing to

w.


the shortness of the collar of the stem: but circumstances occasionally occur which lengthen the organ, so as to give it the real character of a runner, and render the new tuber pendulous (fig. *w*) *.

If we take the Potatoe to exemplify the organization of the tubers of Dicotyledons, we shall find that they resemble, in an equal degree, the stems of the tribe. When a tuber of this plant is cut, either transversely or longitudinally, it appears evidently to be composed of two distinct parts; one of which is internal and cellular, somewhat like the pith or central part of the stem of the plant, and surrounded on every side by the other, which is cellular also but more dense, and bordered with a complicated system of vessels, branches from which stretch into the pith; and that it has a close affinity to the cortical part of the stem.

* The plant from which this figure was drawn was raised in a common garden pot, with the old tuber very near the surface. *a*. The old tuber; *b*. the new tuber; *e*. the attaching process extended so as to assume the form of a runner.

Wherever a gem is formed on the tuber, the pith or central part advances to the surface, and gives a small thread of its substance to the embryon; and this appears to furnish its pith: whilst, in the same manner, the cortical substance, which, although attenuated almost to a pellicle, yet still surrounds the thread of pith, seems to supply its bark*. The vessels also of the tuber tend to each point where a gem rises on its surface; and, when this begins to vegetate, they enlarge so much as to become very perceptible to the naked eye; and acquire a retrograde movement, taking on the functions of absorbents, and conveying the nutritious matter deposited in the tuber to the vascular system of the germe for its evolution and support.

The epidermis of tubers, to whichsoever natural order of plants they belong, is utterly devoid of either absorbing or exhaling organs; and it is this circumstance which fits tubers so admirably for preserving, in an unaltered state, the nutriment deposited in them; the preservation of this in its natural state being absolutely necessary for

* Vide Plate 1. fig. 4. A longitudinal slice of a Potatoe: *a.* the central part, or pith; *b.* the cortical part; *c.* the change in the position of these parts where a gem is given off; *d.* the point where the tuber was attached to the runner. It may not, perhaps, be unnecessary to say that the points on the surface of a Potatoe, called *eyes* in common language, are the gems, the rudiments of the expected plants.

enabling the germe to maintain its vitality. Finally we may, with Sprengel, regard the tuber as a hybernaculum, or winter habitation, for the preservation of the embryon plants yet latent in the gems which it bears *.

The Bulb, the next of the radical appendages which we have to examine, is a globular or pyriform, coated body, solid or formed of fleshy scales or layers, and of a more or less complex structure. It is not peculiarly an appendage of the root, but is found also on the stem and branches of some plants, and even mingled with the flowers of others. As, however, the bulbs which are attached to the root, have several peculiarities which distinguish them from those situated on the other parts of the plant, it is necessary to treat of them in this stage of our inquiries.

The roots of bulbs are simple fleshy fibres, annual productions, which issue either from the circumference of the flattened basis of a kind of caudex on which the scaly and laminated bulbs are seated, or from the substance of the bulb itself,

* Linnæus defines the hybernaculum thus: " *Hybernaculum* " est pars plantæ includens herbam embryonem ab externis " injuriis;" and adds, " estque *Bulbus* vel *Gemma*." Sprengel, in the edition of the *Philosophia Botanica*, which he has edited, very properly adds the tuber. " *Tuber est hybernaculum solidum,* " *substantia marginali molliori cinctum.*"

or from a simple scale when it is solid; and these situations of the roots form the chief characteristic of the bulb, distinguishing it from the tuber, and marking out those limits between the bulb and the tuber, the existence of which is denied by Mirbel * and some other authors: for the roots of the plant borne on a tuber, whether of the closely attached or pendulous kind, always proceed from the stem.

Bulbs, like tubers, are reservoirs of nutriment for the developement and temporary support of the plants formed within them; a fact which is illustrated to common observation by the growing of onions, in the storeroom of the housewife. Young radical bulbs, as I shall soon have occasion to show you, are produced in some instances above, in others below, and in others again within, or at the sides of an old bulb, during the adult vegetation of its plant; and are, like the gems formed on the surface of a tuber, the lateral progeny of the plant itself, not of the bulb. They are more frequently formed previously to the flowering of the parent plant; and as they preserve the plantule within them, until the ensuing spring, they are regarded as winter habitations *(hybernacula)* by Lin-

* "Il n'y a point de limites entre la bulbe et le tubercule; la "transition se fait de l'une à l'autre, par la bulbe solide qui "participe de toutes deux." *Elém. de Phys. vég.* 1[ere] *partie*, p. 135, *nota*.

næus, who points out the close affinity, except in situation*, which exists between them and the buds of trees.

Bulbs may be divided into *solid*, *scaly*, and *laminated*.

I. The SOLID BULB † is a mass of cellular substance, filled with nutritious fluids, and enclosed within a thin epidermis, with vessels running through it from the basis to the apex. It is covered with one or more coats, either of a membranous, or a fibrous, or a reticulated texture ‡. The solid bulb resembles the tuber in several respects; but differs from it in being coated, and, as has been already noticed, in giving off the roots from a radical plate, or from a scale at the basis of the bulb, the point opposite to that from which the shoot is produced.

Solid bulbs may be arranged under three species, taken from the situation on the old bulb where the new one is produced; and thence they may be denominated *superincumbent*, *lateral*, and *enclosing*.

1. The *Superincumbent* solid bulb *(Bulbus solidus superpositus)* I have so named from the new bulbs being produced on the summit of the old one, and appearing, even when they are fully

* "Bulbus est hybernaculum caudici descendenti insidens." *Phil. Bot.* § 85.

† "*Solidus* constans substantia solida." Ib.

‡ Vide Plate 1. fig. 7.

grown, incumbent on it; as exemplified in *Crocus* *, *Ixia* †, &c. The old bulb withers, whilst those which it bears are attaining maturity; but it does not entirely decay away, so as to leave its progeny as distinct and separate individuals, until the new bulbs be formed on them. In some instances, Crocus for example, the plants of the present year, besides exhausting the old bulb for their support, appear to obtain that portion also of their nourishment, which is drawn from the soil, through it; the vessels that proceed from its radical plate passing through the centre of the present year's bulbs, and sending canals even to the rudiments of those formed at the basis of their foliage. This is rendered evident to the naked eye by dividing bulbs of Crocus *sativus*, taken up in the latter end of May ‡. In other plants, as

* Vide Plate 1. fig. 5. Bulbs of Crocus *sativus* dug up in May. *a. b.* the perfected bulbs, adhering closely to *c.* the old bulb much shrivelled; *d.* the radical plate of the old bulb with roots protruded from its circumference.

† Fig 7. Bulbs of Ixia *polystachia* taken up, also, in May. *a. b.* the new bulbs which bear the present year's foliage and flower, partly covered with *c.* the reticulated coat of the old bulb *d.*; *e. e. e. e. e.* the roots of the recent bulbs, protruded between them and the old bulb; *f.* a small bulb appended by a runner as described in the text.

‡ Fig. 6. The bulbs of fig. 5 dissected: *a. b.* the recent bulbs; *c.* the old bulb, with its vessels seen passing up from its radical plate, and continued through the new bulb to the basis of its foliage; *d.* two cords of vessels which

Ixia for instance, although the same course of vessels be perceptible, yet, very thick roots are thrown out from the superincumbent recent bulbs, by which the nutriment is immediately taken up from the soil, without passing through the decaying bulb *. Under certain circumstances of soil, also, wires are protruded from between the more recent bulbs and the old bulb, with small bulbs attached to them †, and these are sometimes so elongated as to give to the lateral progeny a pendulous character.

On dissecting this species of bulb, we find that, besides the outermost coat, which is in general either fibrous or reticulated, it has two others more succulent and fleshy, which appear to form the bases of the sheathing of the leaves, and to cover the whole of the bulb terminating at the plate whence the roots are protruded. Within these is the solid homogeneous mass of the bulb, covered with a thin, beautiful, transparent epidermis, and depressed considerably in the centre, where the stem and part of the foliage are attached; and having cavities also at those points where the young bulbs are formed. The exterior leaves terminate at a kind of shoulder, which sur-

separate from the others immediately after they enter the new bulb, and pass on to the embryon bulbs, forming on *a. b. c.* the embryon bulbs.

* Vide Plate I. fig. 7. † Ibid. fig. 7.

rounds the general cavity; and within the expanded bases of these leaves the young bulbs are seated. As in the case of tubers, although the young bulbs are the production of the existing plant, yet, as has been already remarked, they have a vascular communication with the soil through the medium both of their direct parent and the old decaying bulb*. From this examination the following physiological conclusions may be drawn; that, in this species of the solid bulb, the old bulb is exhausted in the production of the herbaceous part of the plant by the functions of which the bulbs immediately incumbent upon it, and which bear that plant, are perfected, and by which the embryon bulbs, seated on each of them, are also formed. Towards the autumn, the exhaustion of the old bulb is completed; and the vinculum which connects together the bulbs seated on it, and which are now perfected, being thus broken, they separate; and each remains as a distinct being, to be in its turn exhausted, in the production of the plant of the ensuing year, and of its series of bulbs.

2. The *Lateral* solid bulb *(Bulbus solidus lateralis)* is named from the new bulbs being formed on each side of the old, as exemplified in Colchicum *autumnale*. In this species of solid bulb, the

* Vide Plate 1. fig. 6. *d*.

old bulb is completely exhausted, and the new bulbs separated from it before the rudiments of the next series are perceptible. The points of union between the parent and its progeny are near the basis of the bulb on both sides. On dissection, the perfect bulb is found to consist of a mass of cellular substance turgid with moist farinaceous matter; but it is not, as in the former species, perfectly homogeneous, one part being opaque, and the other semitransparent. The vessels run longitudinally through the bulb, from the radical plate to the part whence the foliage springs; and, in their dried up state, in conjunction with the emptied cellular texture and the epidermis, give a tough, spongy character to the exhausted bulb; which, at the time of the separation of the recent bulbs, exhibits the appearance of a shrivelled leathery bag, the roots having dropped from the radical plate *.

* Vide Plate 1. fig. 8, 9, 10, which represent the bulbs of Colchicum *autumnale*, dug up in May, in different points of view. Fig. 8. *a. b.* the recent bulbs (denuded so as to show their true appearance) of an irregular Pear shape, being considerably longer on the side opposite to that by which they are attached to the old bulb, and terminating in *c. c.* a flattened process; on the inner and upper part of which, under a projection formed by the termination of the shorter side of the bulb, is the radical plate, whence the roots protrude. It is half way above this plate, on the one side, and behind the flattened process, on the other, that the new bulbs are formed.

*d.* The

The physiology of this species of solid bulb closely resembles that of the other. The new bulbs are produced by the plant of the bulb to which they are attached, and which is exhausted in the support of the foliage and fructification they bear: and in partly supplying also the nutriment which is deposited in them: I say partly, because it must be kept in mind, that the recent bulbs, of both species, have a direct communication with the soil through their roots; and consequently it is probable that by far the greater part of the matter deposited in them, proceeds from the nutriment obtained from the soil, changed into the proper juice of the plant by the functions of the leaves.

3. The *Enclosing* solid bulb *(Bulbus solidus includens)*, I have named from the circumstance of the young bulbs being enclosed between their

*d.* The old bulb shrivelled up; *e.* the remains of its radical plate; *f.* the remains of its terminal process.

Fig. 9. the back view of fig. 8. *a. b.* the recent bulbs; *c. c.* the flattened processes seen from behind; *d.* the old bulb; *e.* the remains of its radical plate.

Fig. 10. a longitudinal slice of the bulbs. *a.* The old shrivelled bulb; *b. c.* the recent bulbs, in which is seen the dissimilar structure of their mass; *d.* the opaque portion; *e.* the semitransparent: the longitudinal lines in *d.* show the course of the vessels, proceeding from the point of attachment behind the process of the old bulb; at *f.* and on the opposite side, from that above its radical plate at *g. h. h.* the part of the bulbs on which the foliage is seated.

common parents; which, in this species of bulb, are two hemispheres, opposed to each other by their flat surfaces, and united at their bases to the radical plate, whence the stem proceeds *. Its physiology is the same as that of the other solid bulbs.

II. Scaly bulbs consist of fleshy scales attached to a radical plate, and so arranged as to lie over each other like the tiles of a roof. Each scale is a homogeneous mass of cellular substance, thick and fleshy in the middle; but in some instances nearly membranous at the edge, concave on one side, and necessarily convex on the other. Each scale, also, is a distinct reservoir of nutriment, and is endued with such a share of vitality as not only enables it to live if detached from the bulb; but, when placed in a proper soil, to vegetate and produce an entire new bulb. There are two species only of scaly bulbs, the *squamous* and the *granulated*.

1. The *Squamous* bulb *(Bulbus squamosus †)*

* Vide Plate 3. fig. 12. The twofold bulb of cluster-flowered Fritillary (F. *Pyrenaica)*. A. *a. a.* the two hemispheres united at the caudex; *b.* the stem rising between them; *c.* the roots: B. *a.* one hemisphere separated from the other, in order to show the two young bulbs *b. b.* produced on each side of the stem *c.*; the longitudinal line on each marking the place at which the division will take place: *d.* the caudex.

† "*Squamosus* constans imbricatis lamellis. *Lilium.*" *Phil. Botan.* § 85. 1.

is well exemplified in the Lily tribe. If we dig up a plant of one of these, say the White Lily, Lilium *candidum*, in summer, and examine its bulb, we shall find that it consists of concave, fleshy, overlapping scales, each of which is attached at the base to a radical caudex, but is loose at the apex*. A scale, when separately examined, appears to be a homogeneous mass of cellular texture enclosed in a cuticle; the middle being thick and fleshy, but the edges and the apex nearly membranous; a construction, which, on the convex surface, gives it a gibbous or keeled character. The vessels run in longitudinal cords, arranged at equal distances, through the scale; as may be seen in a transverse section of it, if the bulb have been placed for some hours in a coloured solution†. Removing the scales till the stem be exposed, the new bulb is seen formed at its basis; and, by making a longitudinal section of the whole, the manner in which the lateral offspring is connected with the parent plant, through the medium of the vascular system of the stem and of the caudex, is

* Plate 2. fig. 1. The entire bulb of the Lilium *candidum*, as it appears, when taken up in summer, during the vegetation of the stem.

† Fig. 2. A transverse slice of one of the scales, to show the arrangement of the vessels in its substance. The vascular bundles appear like dots; and owing to the cellular texture being more condensed in the immediate vicinity of these, each bundle seems as if it were enclosed in a sheath.

made apparent*. When the new bulb is perfected after the flowering season is over, the exterior scales of the old one decay; and by degrees the stem and a large portion of the old caudex also separate; but as the whole of the caudex does not slough off, and a new portion is added by each successive bulb, it becomes gradually elongated, and at length bears some resemblance, when the scales are taken off, to a cylindrical, toothed, præmorse root. The new bulb, however, is not always found seated close to the stem, in every species of this natural genus of bulbiferous plants. In Lilium *superbum*, for instance, a very thick, succulent, lateral runner is projected from the caudex of the bulb; and, pushing aside the neighbouring scales, advances considerably beyond them, bearing the rudiments of the new bulb on its extremity. Owing to this circumstance, the plant of each successive year rises at some distance from the site of its predecessor; and as the old bulbs do not soon die away, one or two of these, in a decaying state, are generally found

* Plate 2. fig. 3. A. The young bulb as seen at the basis of the stem, when the scales of the old bulb are removed: *a.* the stem; *b.* the young bulb; *c.* the attached fragments of the scales; *d.* the roots of the present year's bulb; *e.* the remains of those of last year. B. The interior of A. divided by a longitudinal section; *a.* the remains of last year's caudex; *b.* the caudex of the bulb of the present year, with the vessels which nourish it anastomosing with those of the parent stem.

appended to the present year's bulb *. On taking off the scales of the bulb, the manner in which the runner, which bears the new bulb, is sent off, becomes extremely apparent †; and the connexion between it and the stem and caudex of the adult bulb is rendered still more obvious, by inverting the cut end of the stem in a coloured solution, and making a longitudinal section of the whole; for, as the vessels in this species of Lily are comparatively large, they can be readily traced, by the naked eye, when filled with the colouring matter, passing from the stem into the caudex, thence into the runner, and through it to the small scales forming on its apex ‡.

* Plate 2. fig. 4. The bulb of the superb Lily, with a small portion of the stem of the plant. *a.* The bulb of the present year; *b.* last year's bulb in a decaying state, with *c.* the remains of the bulb of the prior year still attached to it: *d.* the rudiments of the new bulb attached to the extremity of the succulent runner, shooting forward between the scales; *e.* the roots of the bulb; *f.* roots given off from the stem above the bulb.

† Fig. 5. *a.* The caudex of the bulb denuded of its scales. *b.* the runner projected from it, and bearing the rudiments of the young bulb on its extremity; *c. d.* the remains of former years' bulbs; *e.* the cut stem of the vegetating plant; *f.* the roots of the adult bulb.

‡ Fig. 6. a longitudinal section of the caudex and lateral runner of fig. 5. injected by placing the cut end of the stem in a solution of extract of Logwood: *a.* the caudex, the coloured spots in which show where the bundles of vessels passed off to

It has been already stated, that each scale is not only a distinct reservoir of nutriment; but that it is endued with such a share of vital energy, as enables it, when detached from the bulb and placed in a proper soil, to produce an entire new bulb. In this respect, the scale resembles some leaves, which I shall particularize when we treat of those organs. The scales of the Canadian, and those of the scarlet Pompone Lily, both of which are natives of high latitudes, exhibit this property more readily than any other of the tribe. The young bulb rises either from a callus formed at the base, or the margin of the scale *; which gradually decays away as the bulb enlarges; and finally separates from it as soon as a sufficient number of roots are produced to support this lateral production as an independent being. The bulbs, however, which are thus propagated, differ from those formed in a more direct manner, as they produce leaves only; and several successions of leaf bulbs are propagated in a direct line from them,

the scales of the adult bulb; *b.* the stem with the vessels injected; *c.* the runner, with the vessels running through it to supply the rudiments of the young bulb on its extremity; *d.* a scale of the young bulb; *e.* the place where the runner that supported the adult bulb was broken off.

* Fig. 7. a scale of Lilium *pomponium*, with two bulbs, *a.* and *b.* forming on it. Fig. 8. a portion of a scale of Lilium *superbum* with a bulb formed on its edge; *a.* a root already protruded from the bulb.

before a flower bulb is produced. It may seem extraordinary that no formation of young bulbs occurs on the scales individually, when they are allowed to remain attached to the old bulb; but when we consider that in this case their vital energy, and the nutriment they contain, are exhausted in supplying the growing plant, and aiding the formation of its lateral progeny; and that, on the contrary, when a scale is separated, the formation of the new bulb is merely the employment of the same agencies, which would have acted simultaneously with the other scales had the separated scale been left in its original state, only differently directed, the explanation is obvious. Another question, however, arises on this point. If, as has been stated, the young bulb be the production of the joint action of the bulb and the plant, how is the bulb on the solitary scale formed? I confess my inability to solve this question; and can only remark, that the bulb formed on the separated scale is, comparatively, a very imperfect being; and the formation of a series of bulbs in a direct line from it, each progressively more perfect than its precursor, is requisite before a bulb can be produced as perfect as that one, which is the effect of the joint functions of the plant and of the ripe or adult bulb: and in this progression to perfection the plant of each season necessarily plays its part.

2. The *Granulated* bulb *(Bulbus granulatus)* is named from its appearance being that of a small, globular body, or grain. It is found usually associated with many others, studding, as it were, the root to which they are affixed; as is beautifully exemplified in that of grain-rooted Saxifrage, Saxifraga *granulata* *. On examining a single bulb, we find that it is composed of slightly curved granular scales, covered with two coats †, and enclosing the plantule, which, on vegetating, bursts the coats and shoots up between the scales. As it advances, these are gradually emptied, until the epidermis only remains like a small shrivelled leaf; whilst fresh bulbs are generated upon runners, sent off from the basis of the herbage. The minuteness of the scales prevents their structure being examined by the unassisted eye; but, with the aid of the microscope, it is perceived to be nearly the same as that of those of the squamous bulb.

III. Laminated bulbs are composed of fleshy layers, attached at the base to a solid radical caudex. Each layer consists of a plate of cellular substance, filled with secreted juices, and enclosed between two cuticles. Bundles of ves-

* Vide Plate 2. fig. 9. which represents the bulbs congregated on the runner of the plant *a*.

† Fig. 10. *a*. a bulb denuded of its coats, with the plantule in a state of vegetation; *b*. a plantule separated from the enclosing scales, attached to the radical plate, and a small fragment of the tunic.

sels run vertically through each layer, communicating with those of the caudex, the stem, and the roots: these are entire and porous vessels; but in some of the laminated bulbs, the spiral vessels are so numerous as apparently to make up the greater part of the substance of the layers. There are two species of laminated bulbs; the *concentric* and the *nestling*.

1. The *Concentric* laminated bulb *(Bulbusconcentricus tunicosus)* consists of sheathing laminæ, each enclosing, or nearly enclosing, the other from the centre to the exterior coat or tunic. This species of laminated bulb may be subdivided into two sections; the first comprehending those bulbs in which the layers are *entire*, or in which each layer is the sheath, as it were, of those within it; and the second, those in which the layers are divided, or only overlap those within them, but do not form an entire sheath, as in the former instance.

* *With entire Layers.*

The most familiar examples of this division are the common Onion, Allium *Cepa*, and the members of the Narcissus tribe. In these, the caudex is of an irregular, semiorbicular form; and consists of a central cellular part or pith, covered by a more solid envelop or cortex, which is interposed betwixt the basis of the layers and the pith, and forms also the proper radical plate, whence



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the roots are protruded. The number of the layers varies: the exterior are thin and semipellucid, being formed simply of two membranous cuticles, with equi-distant bundles of vessels running longitudinally through them: the interior are more fleshy, the cells being filled with nutritious juices. A transverse section of the bulb exhibits the continuous character of each layer *. The new flower bulb is formed nearly in the centre of the old bulb, at the base of the stem; but in general, there are several leaf bulbs formed: one or more within the second or the third layer from the surface, and others laterally and altogether exterior to the old bulb. The outer layers only of the old bulb are completely exhausted in one season; hence the bulb in several subsequent seasons appears to be the same which originally flowered, only much enlarged. The lateral bulbs separate, and, as in similar cases, maintain an independent existence. In the Tulip, the bulb consists usually of four concentric layers only (independent of the common coat), the outermost of which may be termed fleshy; but being nearly diaphanous, the longitudinal vessels are seen running through it at equal distances, with the intervening spaces on

* Vide Plate 3. fig. 1. which represents the transverse section of the bulb of Narcissus *Jonquilla*: *a. a.* two young bulbs rising betwixt the second and third layers; *b.* the roots protruded from the radical plate, which is hid by the position of the bulb.

the inner surface studded with opaque slightly elevated glands, which produce correspondent depressions on the outer surface of the next layer. The other layers are fleshy and thick in proportion as they approach the enclosed plantule, or centre; and, although the depressions of the glands be visible on the exterior of each, yet, from the turgidity of the cellular texture, neither these nor the vessels are perceptible in them; but by placing the bulb in a coloured solution for twenty-four hours, and then making a transverse section of it, the latter are seen like coloured points arranged in a regular series, and nearly equi-distant from the enclosing epidermis of each layer *. By tearing the layer longitudinally opposite to any of these points, the vessels can be traced downwards through the substance of the layer, and even into the radical plate.

In this bulb, the stem, which bears both the foliage and the flower, rises from the centre of the bulb; but as soon as the new bulb, which is formed close to its base, enlarges, the enclosing laminæ of the old one begin to lose their succulency and plumpness; and this exhaustion con-

* Plate 3. fig. 5. a transverse section of a Tulip bulb, during the flowering season. *a*. Section of the stem; *b*. remains of the exhausted layers of the old bulb; *c*. the new bulb, which should flower next season; the dots in the layers showing the positions of the longitudinal bundles of vessels.

tinues to keep pace with the enlargement of the offspring, until the layers are completely emptied. They then decay away, and leave the stem partially covered with the void cuticles on the outside of the new bulb *. The stem itself, with the old radical plate, next die away; while the new bulb, after remaining as it were in a state of inactivity during the winter, shoots out fresh roots from its radical plate in the spring, and runs the same course as its predecessor. Under favourable circumstances, two or three new bulbs are sometimes formed in the same season; but these are usually only leaf bulbs †.

In long-rooted Allium (Allium *victorialis)* the concentric sheathing layers (each of which, as in several other species of the genus, is expanded into a leaf) are of a reticulated texture ‡; and

* Fig. 6. a longitudinal section of a Tulip bulb, during the flowering season. *a.* Section of the stem; *b.* the remains of the old bulb; *c.* the new flower bulb enveloped in *d.* its sheath or exterior coat; *e.* the rudiment of the caudex of the new bulb, where it separated from the parent stem.

† Plate 3. fig. 4. a bulb of the common Tulip taken up in the flowering season. *a.* Part of the stem, which is cut off; *b.* the exterior layers of the exhausted bulb, enveloping both the new flower bulb *c.* and an offset, or lateral leaf bulb, the stem from which is seen at *d.*

‡ Fig. 2. a bulb of long-rooted Allium. *a.* The outer layer of the present year's bulb, extended into the sheathing stem; *b.* the reticulated layers, loose both at the caudex *c.* and above; *d.* the roots of the existing bulb piercing the network of the reticulated layers.

when exhausted of the nutriment contained in them, assume the appearance of lacework. In this bulb, also, the young bulbs are formed within the second layer of the present year's bulb *.

* * *With divided Layers.*

In this division of the concentric laminated bulbs, the layers, as has been already stated, do not form an entire sheath. In the garden Hyacinth (Hyacinthus *orientalis),* which I select as an example because it can be easily procured, they comprehend two thirds only of the circumference of the circle. Each layer is fleshy and thick in the centre, and becomes gradually thinner towards its edges until it terminates in a membranous film, embracing the layers within it in the same manner as the hand holds a ball which it cannot completely enclose. The deficient portion of each layer is always on the opposite side to that of the layer immediately beneath it. The caudex has the character of a segment of a hollow sphere, on the convex surface of which the layers are attached; whilst a considerable number of fleshy roots protrude from the circumference †. The

* Fig. 3. a vertical section of the same bulb. *a.* the successive succulent layers extended into the stem; *b.* the exhausted reticulated layers; *c.* the caudex; *d.* the young bulb.

† Vide Plate 3. fig. 6 and 7. *a.* The body of the bulb; *b.* the manner in which the layers overlap each other; *c.* the radical plate, with the roots separated from one side of the cir-

vessels run in longitudinal bundles through the layers; and so numerous are the spiral vessels in this description of bulb, that, in the Amaryllis tribe, the Squill, and some other of the larger bulbs, on breaking a layer transversely, they may be drawn out to the distance of three or four inches; and from the strength of their component fibres and their number, they are capable of supporting the pendulous portion of the layer. I have also been informed that the fibres of the spiral vessels of the bulb of some species of the Blood-flower (Hæmanthus) have been spun into thread and manufactured, which I can readily believe, from the strength of a thread which I have formed from the spiral fibres of the layer of a bulb of Brunsvigia *toxicaria*, Poison-bulb, by merely twisting them in my fingers. On making a transverse, or a longitudinal section of the Hyacinth bulb, we find one or more young bulbs seated between the layers *; and that one which is nearest

cumference, to show its concavity; *d.* young lateral bulbs, which produce leaves, and a new bulb when detached from the parent; *e.* a bulb, which has produced leaves this season, formed within the coats of the old bulb.

* Vide Plate 3. fig. 8. and 9.—Fig. 8. *a.* The caudex, as it appears in the longitudinal section of a full-grown bulb of Hyacinthus *orientalis*; *b.* a young bulb forming with the outermost fleshy layer; *c.* the remains of the stem and foliage of the present year's plant. Fig. 9. a transverse section of another bulb of the same species of plant, showing the terminations of the

to the centre of the old bulb is, usually, the real flower bulb for the next season; for, although, owing to a few of the outer layers only decaying, the old bulb appears still to yield the flower, yet, this actually springs every year from a new bulb formed within the old one. Young leaf bulbs are also protruded exteriorly from the base of the old bulb; and these appear to be really the production of the bulb itself; for the Dutch cut their bulbs transversely, after they have attained a certain size; and plant the lower half, in order to multiply the number of the lateral bulbs; whilst the flower bulb, as has been already stated, is evidently the result of the combined functions of the plant and the bulb.

No experiments, at least that I know of, have been made, to ascertain whether a layer of any of the concentric laminated bulbs, when separated from its caudex and planted, will produce young bulbs, as is the case with the scales of the squamous bulbs; but I am of opinion that if an en-

layers, and the divided bundles of longitudinal vessels. *a.* the lower portion of the flower stem; *b.* the bulb which will flower next year, gradually expanding the old bulb by its growth; *c.* the roots attached to the caudex, which are hid by the position of the superincumbent parts. Fig. 7. another bulb of the garden Hyacinth in which four young lateral leaf bulbs *d.* are seen seated on the caudex, to show the manner in which these lateral offsets generally occur.

tire layer were carefully separated from its caudex, and planted, it would produce young bulbs upon its basis.

2. The *Nestling* bulb *(Bulbus nidulans)* is composed of entire concentric layers, which terminate in sheathing leaves, and enclose within each, from the circumference to the centre, several young bulbs; so that, when the layers are partially ruptured, the whole seems to consist of small bulbs, and has a nestlike appearance *. The layers are more membranous than those of the other laminated bulbs we have examined; and consequently display, more evidently, the longitudinal equi-distant bundles of spiral and entire vessels. The caudex is very vascular; in form nearly an inverted truncated cone, and protruding a great number of long threadlike roots.

On dissecting the young bulbs, enclosed within the old one, we find that those only which have already shot up into leaf, contain small bulbs or their rudiments within the layers; hence, there is reason for concluding that the young bulbs are in this instance, chiefly the result of the functions of the plant. In the bulb of Garlic, Allium *sativum*,

* Vide Plate 3. fig. 10. the recent bulb of Garlic, Allium *sativum*, with the sheathing layers partially removed to exhibit the young bulbs. *a*. The young bulbs; *b. c. d. e.* remains of the sheathing layers; *f.* the caudex.—Fig. 11. a longitudinal section of the same bulb. *a*. the caudex; *b. c. d.* the sheathing layers, which terminate in leaves.

the odorous, acrid, secreted juice which characterizes it, is found in greatest quantity in the fleshy internal layers of the young bulbs * ; and consequently these are the parts employed both medicinally and as a condiment; whilst, in the membranous layers of the old bulb, it is scarcely perceptible either to smell or to taste.

Such are the characteristic distinctions of those appendages of roots, which are denominated *bulbs*. They have been properly regarded by Dr. Darwin † and others as subterraneous buds; and as having a close affinity with the buds on the stem and branches of perennial plants: for, like these, they continue rather than reproduce the individual, and are liable to all the hereditary imperfections and diseases of the parent. In some other particulars also this resemblance holds good; for, as in all plants which are furnished with buds, those produced in the first years of the plant are leaf buds only, and a succession of these occur before flower buds are formed, so no flower bulb is ever produced from seed; the first formed being always a leaf bulb, which, in many instances (as the Tulip for example), produces another leaf bulb, and so on for several successive generations, until at length a flower bulb is formed; after which, one

* In common language these young bulbs are termed *cloves*.

† *Phytologia* passim.

flower bulb at least is produced every season. Many circumstances connected with the physiology of bulbs might be treated of in this place; but, as I shall have again to recur to them in noticing those bulbs which are formed on the stem, and among the flowers of many plants, I shall defer at present the further consideration of this part of our subject.

And being now acquainted with the forms which characterize roots and their appendages, we shall, in our next Lecture, finish the consideration of these vegetable organs.

## LECTURE V.

### THE SUBJECT OF THE FORMER LECTURE CONTINUED.—OF SOILS AND MANURES.—OF THE MEDICINAL AND DIETETICAL PROPERTIES OF ROOTS.

THE usual situation of roots is in the ground; but many plants, although their seeds be sown in the earth, yet, will not vegetate in it, their proper soil being the bark of other living plants. Such are named parasitical, owing to their nourishment being obtained from those plants on which they fix, and which they rob of a part of their juices, often injuring them to a very considerable degree. The Misletoe (Viscum *album)*; the Broom Rape, Orobanche; the majority of Lichens; the Mosses; some of the Ferns; many of the Orchis tribe; those minute fungi, which produce the diseases of corn and of some grasses, known by the names of rust, blight, and mildew; the Sclerotium *crocorum*, a sort of tuber which attacks the bulb of the Saffron; and the Dry Rot, to the destructive powers of which the noblest specimens of architecture occasionally fall sacrifices; are parasitic plants. Some of this description of plants, however, originally grow in the earth, and do not lose their attachment to it

until they find another plant to lay hold of, and into which they can dip their caulinar roots, or rootlike absorbents, which are protruded from the stem, in order to share its nutriment, and on which they are afterwards supported; as, for example, the Cuscuta, or Dodder *, which may be regarded as the natural parasite of our indigenous Heaths and Hops.

Some plants, after they have arrived at a certain age, do not even require that their roots should be fixed to any spot; but maintain life on what they can procure by absorption from the atmosphere. Such are the Cacti, a curious tropical tribe of succulent plants; on which account one of the species, the Indian Fig, Cactus *opuntia*, was recommended to the notice of seafaring people, by the late Dr. Anderson of Madras, for the purpose of supplying vegetable food on long voyages; and as a preventive of scurvy. But the most curious instance of this kind is the aërial flower, Epidendrum *flos aëris* †, an East Indian parasitical plant, which continues to grow, blossoms, and even perfects its seed, when it is torn

* The Dodder germinates in the earth, and rising above it, shoots out filiform stems, which twine around the neighbouring plants. Its original root now decays, and a kind of warty roots are formed in the stem at every point where it touches the supporting plant by which it is nourished.

† Aërides *matutinum* of Willdenow.

from the tree on which it originally grew, and is suspended in the ceiling of an apartment *. Many aquatic plants, also, have roots which serve no other purpose than to fix them for a short time to the spot where they have germinated, from which they afterwards separate and float upon the surface of the water; thus the common Duck Weed, Lemna *minor*, which rises to the surface almost as soon as it has germinated, has filiform roots from three to six inches in length, which hang perpendicularly in the water, and having no attachment to any body, allow the plant to float freely in every direction.

* Mr. Macnab, superintendent of the Botanic Garden at Edinburgh, has published an account of a suspended plant of Ficus *Australis* (Ferrugineous Fig), which had grown for eight months, up to the time of publishing his paper, February 7th, 1820, without earth, in the stove of that garden. The plant, which was originally growing in a pot in the greenhouse, on being removed into the stove, and treated in a peculiar manner, threw out several roots from the stem; after which the earth was gradually removed from the original roots, and the plant left suspended in the air, affixed to the frame of the stove. Water was, however, sprinkled over the whole plant every day. "What," adds Mr. Macnab, "may appear rather remarkable is, that though this Ficus is a plant by no means free in producing fruit in the usual way of cultivating it, this specimen, quite suspended, without a particle of earth, was loaded with Figs during the months of September, October, and part of November." *Edinburgh Philosophical Journal*, vol. iii. p. 77.

All subterranean roots assume a particular direction; which is constant in every individual of the same species of plant. They are said to be *perpendicular (perpendicularis)* when the caudex, or main body of the root, extends perpendicularly into the ground, as exemplified to the majority of fusiform roots (p. 130), and in the main or top root of most trees: and *horizontal (horizontalis)* when the extension is nearly parallel to the plane of the horizon, so that the root forms nearly a right angle with the stem or herbaceous part of the plant; as, for instance, in Winter Green, Pyrola *umbellata*, Sweet Flag, Acorus *calamus*, and in the majority of the articulated roots. Many of the horizontal roots, whilst they run under the surface of the ground, push up stems at intervals so as to multiply the plant; thence the appellation *creeping* roots (R. *repens*): as in common Spear Mint, Mentha *viridis;* Couch Grass, Triticum *repens;* Bulbiferous Coral Wort, Dentaria *bulbifera*(fig. *x*), and many other plants. And this property renders some weeds extremely obnoxious to the farmer: for, if any portion of a creeping root be

*x.*

left in the soil, it will throw up a new stem, which in its turn produces an extension of the root. But if it be injurious in some instances, it also serves very important purposes in the economy of nature. Thus the sand Reed-Grass, Carex *arenaria*, by means of its creeping roots, binds together the dry sand of the flats on the sea-shore where it grows; and assists not only in forming a fertile soil where sterility would otherwise reign; but by preventing the sand from drifting, preserves from destruction the neighbouring fields, which already repay the labours of the agriculturist.

We must not, however, confound the creeping with the *progressive* root (R. *progrediens)*, which, in extending itself, likewise shoots up stems and herbage at intervals; since it differs in this circumstance, that as it advances anteriorly it decays posteriorly; thus causing an obvious progression of the plant; and at the same time limiting in a considerable degree its multiplication. Its direction also is not necessarily horizontal, like that of the creeping root, but may be perpendicular; the cause of the progression in that case being the production of a new root laterally: and, in this respect, these roots, although the caudexes are not tubers, yet have a close affinity with the attached tuberiferous roots. Thus the root of officinal

Monkshood, Aconitum *neomontanum* (fig. *y*), affords an excellent example of the progressive conical root; *a.* the old root supporting *b.* the lower portion of the stem; *c.* the new root attached by the lateral offset *d.* to the basis of the stem *b.*: so that the new stem, which should have arisen from the bud *e.* would have been about one inch from the old plant, had it been left in the ground. The

*y.*


moniliform roots (p. 142), also, are progressive; as those of Pæony, Pæonia *officinalis*, and night smelling Geranium, Pelargonium *triste;* but in these the progression is made by suckers thrown up from the nodules; such roots in this respect resembling the tubers on the pendulous tuberiferous roots. The difference, however, between the progressive roots and the tuberiferous, is very obvious; the caudexes and nodules in the former being real roots, furnished with lateral rootlets issuing from their surface; whilst the tubers, in

the latter, are appendages only to the real roots, which are fibrous and issue from the basis of the stem, or the herbaceous part of the plant, and not from the surface of the tubers.

Besides these roots which take the perpendicular, or the horizontal direction, there are some that assume an intermediate one, in which case the root is said to be *oblique (R. obliqua);* but, as in general, there is always an approximation either to the perpendicular or the horizontal, the truly oblique root is very uncommon. In observing the position of roots in the ground, it should be recollected that it is the main root or caudex only which determines this point; and that, whatever its direction may be, that of the rootlets is always different: thus, in perpendicular roots, the rootlets spread either horizontally or obliquely; whilst in the horizontal and the oblique they descend perpendicularly; or, in every instance, they form an angle more or less acute with the surface of the caudex. The main root should be entire, also, before its direction or character can be accurately ascertained; for, if the apex be destroyed by any means, the caudex no longer elongates; but sends off lateral shoots, which necessarily take an opposite direction from that which is natural to the root.

The situation of the root, in regard to the stem or the herbaceous part of the plant, is ge-

nerally at the base; but roots originate from that part also of the stem which is above ground. Thus the Strawberry throws out lateral shoots, which are termed wires, from which roots descend at intervals into the ground; and from the stems of the Ivy, the Jasmine, the Ash-leaved Trumpet-flower, Bignonia *radicans*, and other plants which fix themselves to walls and rocks, roots are protruded, serving equally to imbibe nourishment and to give support to those climbing plants. Whenever a stem is surrounded with earth, roots are protruded from it. Du Hamel filled a cask with earth, and boring holes through the bottom of it, supported it on stakes three feet from the ground. He then pushed slips of plants through the earth in the barrel, and planted their ends, which passed out at the holes in the bottom of the cask, in the ground below it. These ends took root; the parts between the ground and the cask put forth branches and leaves; those surrounded by the earth in the cask protruded roots; and those, again, above it became clothed with foliage. It is, also, well known that, if a twig of a Willow be bent and each end of it stuck into the ground, roots will be protruded from both extremities, whilst the middle or arched portion will be covered with leaves and branches; and the extremities of the branches of all ligneous plants throw out roots,

if they be bent down and laid under the earth. Indeed it is not absolutely necessary to lay them under the ground to produce this effect; for a ligneous plant growing in a sterile soil, provided the situation be shady and the air damp, will throw out roots from its branches, resembling those protruded by Ivy. I have in my possession a portion of the branch of a Bay, Laurus *Indica*, in the whole length on one side of which the bark is ruptured, owing to the protrusion of numerous short rootlets. The plant from which this branch was cut, was growing (in 1814) in a kind of cave, formed by the intertwining roots of a noble Beech, on the summit of a chalky bank, in Lord Derby's grounds, near Epsom. The chalk had mouldered away from under the roots of the Beech, which, projecting forward as a roof, shaded the Bay that, perhaps, had been originally planted close at the foot of the bank: but all the soil had been long since washed away from its root, which adhering to the bare chalk, served no longer as an absorbing organ, but merely to sustain the plant in its upright position; and as there were very few leaves on the branches, the rootlets, which were protruded from them, evidently maintained the life of the plant, by absorbing the water held in solution in the air of the shady spot where it grew. On the knowledge of facts such as these, plants are propagated by what are called layers, an opera-

tion, which consists in bending down a branch, or the stem of the plant, so that the knee or bent portion of it can be preserved, by means of pegs, under the surface of the soil. The part so treated is nourished by the parent plant, until roots are sent off from the part under the ground, when it is cut away, and thus becomes an independent plant. Some plants naturally propagate, or rather extend themselves in a similar manner. Thus, from the branches of the Banyan or Indian Fig-tree (Ficus *indica)*, fibres are thrown out, which hang suspended like icicles, and grow thicker as they reach the surface of the ground, into which they strike root and become trunks, the branches of which root again in the same manner: and this progression of increase is continued until the ground is covered to a prodigious extent with an umbrageous labyrinth or grove, formed from one original trunk, impenetrable to the sunbeams *. One of these trees, called Cubber Burr, situated on an island in the river Nerbedda, exceeded 2000 feet in the circumference of its shade; and in 1787, had 350 trunks. Religious festivals were held under its luxuriant canopy, which was capable of affording shelter from the solar heat to

* Pagodas are generally built in the neighbourhood of these trees; and under their friendly shade the Brahmins and devotees perform their religious rites.

7000 persons. MILTON has immortalized the Banyan, by describing it as the tree under which our first parents retired to hide themselves after their fall:

They chose
The Fig-tree; not that kind for fruit renown'd,
But such as, at this day to Indians known
In Malabar or Decan, spreads her arms
Branching so broad and long, that in the ground
The bended twigs take root, and daughters grow
About the mother tree, a pillar's shade
High over-arch'd, and echoing walks between: &c.

*Paradise Lost.*

The structure of roots does not differ materially from that of the trunk and branches; we may, therefore, reserve the minute examination of that part of our subject until we come to treat of these organs; and, at present, notice only their general structure *. All roots are either *ligneous* or *fleshy*. The ligneous belong to trees and shrubs, and are composed of an epidermis or scarf-skin, a cutis or bark, a vascular system, woody matter, and pith. The fleshy, which belong to herbaceous

* The analogy, indeed, is so close, that a tree may be inverted so as to change the roots into branches, bearing leaves and flowers, and the branches into roots producing radicles. This fact has been frequently proved, by repeating the experiment (first tried by Du Hamel) of planting a tree with the branches in the ground, and leaving the roots in the air; after a season the buried branches produce radicles, and the roots raised in the air give out buds, stems, and leaves.

plants, consist chiefly of cellular and vascular textures, interspersed with slender bundles of woody fibre. In both the epidermis or exterior covering is the same, and seemingly destitute of vessels: it is present in every stage of the growth of the root from its origin, on the radicle of the embryon, to the tangled rugged arms which rivet down the venerable monarch of the wood, the pride of centuries: it serves the office of a filter, and allows nothing to pass through its pores that cannot enter the minute mouths of the absorbent vessels which open on the surface of the bark beneath it. The epidermis of roots is thus adapted for its situation in the moist soil; but, in other respects it does not differ from that which is spread over the stem, branches, leaves, and every other part of the plant. The *fibrils,* which are attached to all roots, whatever may be their figure, are, as has been already stated, mere bundles of vessels enclosed in a cuticular membrane; and, as they take up from the earth the food of the plant, they are, in fact, the real roots; whilst the caudex may be regarded as a magazine, in which the food that has been elaborated into the proper juice is deposited for the particular uses of the vegetable economy; and it is this deposition which affords the colour and odour which distinguish different roots.

With regard to the mode of growth of the

root, Mr. Knight has advanced sufficient reasons for believing that this organ is not an elongation of the radicle; but is formed upon it after the germination of the seed by successive increments of new matter deposited at its apex; for, whilst the root never elongates by the extension of already organized parts, the radicle does elongate throughout all its parts in the germinating seed. The root, at first, consists of cellular matter only, contained in an epidermis, within which the cortical vessels are afterwards generated; the circle of vessels, says Mr. Knight, "enclosing within it a small portion of the cellular substance, which forms the pith, or medulla of the root; and these vessels gradually generate alburnum, which, in a transverse section of the root, appears arranged in wedges round the medulla." The same able phytologist further maintains that root shoots differ from stem shoots in not being emitted from the alburnum; and that the presence of the alburnum is not essential is evident from the fact, that leaf-stalks, which contain no alburnum, nevertheless emit roots; and these derive their existence, as in all other cases, from the proper juice conveyed in the returning vessels *.

All roots have originally more or less of a tapering form; which is partly the consequence

* *Phil. Transactions*, 1809.

of their mode of growth; for, as has been just stated, a root, in extending, is not lengthened through all its parts, but by additions made to the extremity, and as these, in the early stages of its growth, are made more rapidly than the alburnous depositions, which add to its diametrical dimensions, its shape must necessarily be tapering. That the longitudinal extension of the root is effected by the deposition of new matter at its extremity, was first ascertained by Du Hamel *, who having passed small pieces of silver thread transversely through a vegetating root, at distances which were accurately measured, found that the upper threads, those nearest to the stem, or herbage, retained their original and relative situation, whilst that one only which was very near to the end of the root was carried down; and this is the case both in succulent and ligneous roots. The lateral extension, on the contrary, in succulent roots, appears to depend on the deposition of additional particles, throughout the whole of their substance; and in perennial and ligneous roots, by the formation of an annual new alburnum, in the same manner, as I shall explain to you in its proper place, occurs in the stems and branches of trees and shrubs. When the extremity of a root is destroyed, or when the root has attained the

* *Phys. des Arbres*, liv. I. c. v.

natural limit of its longitudinal extension, it throws out lateral branches; and these extend with most vigour in that direction in which the most abundant supply of nourishment is to be found; a circumstance which has been very unaccountably attributed by some to a sentient, or an instinctive principle in plants. The fact is, that the influence of a quantity of manure, or of richer earth, is not confined to the immediate spot where it is deposited; but extends to a certain distance in every direction, diluted, as it were, by the poorer soil, until its power is altogether dissipated: as soon, therefore, as any branch of a root impinges upon the limits of this circle, it obtains a supply of nutriment capable of exciting its vital energy in an increased degree: and as this augments in a direct ratio, as it extends, this branch in length and vigour necessarily far exceeds those on the opposite side of the main root, which have had a more scanty supply of nourishment. Thus, also, if a seed of a tree, conveyed by the wind, or otherwise, as may accidentally happen, be planted on the top of a wall, its roots will gradually extend until they reach the ground; whilst the upright growth of the tree will be very scanty previous to the root establishing itself in the soil. Sir J. E. Smith, in referring to a fact of this kind, communicated to him by the Rev. Dr. Walker of Edinburgh, regarding an Ash, which grew on a wall in the Canon-

gate in that city, and which I have seen, explains it in the following manner:—"Here the vital powers of the tree not being adequate, from scanty nourishment, to the usual annual degree of increase in the branches, were accumulated in the root, which, therefore, was excited to an extraordinary exertion, in its own natural direction downwards." I would, however, say that it was owing to the moisture of the earth soaking into and ascending the wall, a fact which, from every day's experience, we know takes place, that the root extended in the direction of its natural stimulus, the moisture; the real exciting cause of its increased exertion: and the accuracy of this opinion is placed almost beyond controversy, by the experiment of Mr. Knight, which I am about to relate. Some Beans were placed in pots filled with earth, but were half covered only with the mould. The pots were then inverted on a grating of wood, so as to support the earth and the Beans, in such a manner, that the earth was above and the air beneath each radicle as it was emitted. Water was next introduced through the bottom of the inverted pots: the radicles extended horizontally along the surface of the mould, and in contact with it; and in a few days emitted many fibrous roots upwards into it, which passed through one half of the mould. We may, therefore, venture to assert, that although the natural direction of the radicle

is, in every instance, downwards, depending on causes which have not yet been ascertained *; and although roots, during their growth, assume various directions, which invariably occur in the same kinds of roots, yet, that circumstances connected with their mode of growth, produce deviations, and affect the uniformity which might otherwise be expected. But many roots not only vary from their natural direction, but even change their characteristic figure, owing to circumstances connected with the state of the soil: thus, insulated trees, that are much agitated by the wind, have strong lateral roots, forming a kind of network that adheres firmly to the earth; whilst the same description of trees, growing in a forest, has long slender tapering roots. This diversity may be thus explained: when a tree stands alone, the soil near the surface is partially loosened by the agitation of the tree by the wind, and consequently less opposition is afforded to the extension of the lateral branches of the root, than the unmoved ground offers to that of its perpendicular caudex; whereas, when a tree grows in a forest, the mechanical obstacles offered to the extension of the lateral roots by the neighbouring roots, ex-

* The different opinions that have been hazarded on this subject shall be noticed, when we take under our consideration the germination of seeds.

ceed those which the ground offers to the perpendicular. Some Grasses, also, as the common Cat's Tail, Phleum *pratense,* floating Fox Tail, Alopecurus *geniculatus,* and others, which in a wet situation have fibrous roots, became nodose, when planted in a dry sterile soil: the cause of which cannot be better explained than in the words of Sir J. E. Smith. Presuming the herb to be starved, he adds, "by a failure of the nutrimental fluids hitherto conveyed by the water of the soil, its growth would be checked; and when checked, the same growth could not, as we know by observation on vegetation in general, be instantaneously renewed. A sudden fresh supply of food would, therefore, cause an accumulation of vital energy in the root, which would consequently assume a degree of vigour and a luxuriant mode of growth not natural to it, and become bulbous. Thus, it acquires a resource against such checks in future, and the herb is preserved alive, though in a very far less luxuriant state than when regularly and uniformly supplied with its requisite nourishment *."

The nature of the *fibrils* has been already mentioned. They may be regarded as the mouths of the plant: for, the extremities of their vessels being open, these suck up such fluid nutriment

* *Introd. to physiol. and systematical Botany,* p. 115.

from the soil as can pass through the pores of the epidermis, and conduct it to the caudex, or main root, through the vessels of which it ascends to the leaves: there it is as it were digested; and, being changed in its properties, is again conveyed by another set of vessels to the caudex, in which it is deposited for the future exigencies of the plant. As a proof that the fibrils are the only parts of the root which take up the nutriment of the plant from the soil, Mirbel remarks, that "herbs perish at the foot of young trees, because the fibrils issuing from the collet (the point of connexion of the stem and the root) exhaust the ground; but old trees extending their vigorous roots to a distance, allow the plants, which are close to them, to subsist and destroy those which are more distant." It has not yet been ascertained whether the fibrils are strictly annual productions, an opinion which was maintained by Du Hamel *, Mirbel †, and Sir J. E. Smith ‡, and adopted by Wildenow §; but which is doubted by Mr. Knight, who, although he admits that in roots of trees, or ligneous plants, crowded together in a garden-pot, the fibrils are often found lifeless in the succeeding spring; yet, remarks that he has "not

* *Phys. des Arbres.*

† *Traité d'Anatomie.*

‡ *Introd. to physiol. and system. Botany.*

§ *Principles of Botany, Eng. trans.* § 260.

observed the same mortality to occur, in any degree, in the roots of trees when growing, under favourable circumstances, in their natural situation *." My own experience does not authorize me to decide with confidence on this question; but it rather induces me to incline to the opinion that they are annual productions.

In duration, roots are either annual, biennial, or perennial. Annual roots belong to those plants which are produced from the seed, grow to their full extent, and die in one year or season; as, for example, Barley, Hordeum *secale;* the White Poppy, Papaver *somniferum;* the common Pea, Pisum *sativum;* the garden Bean, Vicia *faba*, &c.: biennial to those that live through the winter of the year in which they are produced, and after flowering and yielding seed, die in the following year, as the Carrot, Daucus *carota;* the genus Teasel, Dipsacus; the Canterbury Bell Flower, Campanula *medium*, &c.: and perennial to those that blossom and produce seeds through many successive seasons, as the majority of herbaceous plants and all shrubs and trees. But the life of annual and biennial roots may occasionally be protracted much beyond its natural period, when any circumstance occurs that can prevent the plant from flowering, or, even when it does flower,

* *Phil. Trans. Part* 1. 1809.

from perfecting its seed. Thus I have preserved the life of a Sweet Pea until after Christmas, when it was destroyed by the severity of the weather, by nipping off the flowers as soon as they were fully blown; and plants of tropical climates, which are naturally biennial, sometimes live for many years in our hothouses; but they all invariably die after they have produced fruit. The cause of this is, that the vitality of the plants of this description seems to be sufficient for continuing their life only till after the formation of the seed, the natural means of perpetuating the species; in perfecting which, the irritability and life of the individual are completely exhausted; and, with the plant, the root perishes. In perennial plants, the fibrils only annually perish and are renewed; they decay before the leaves fall in autumn; and are again formed in the early part of spring. At least this is the opinion commonly received. The root, however, enjoys more vitality than any other part of the plant, and can reproduce all the other parts, when the tree is cut down or otherwise destroyed; except in the Pine tribe and some other dry resinous plants.

Such is the ROOT—an organ of the greatest importance, whether we consider it simply as fixing the plant in the ground, and enabling it to elevate its leaves and flowers in the air; or, in a more important point of view, as selecting and taking up

from the soil the materials fitted for the nourishment and support of the vegetable body.

It is a wise provision of nature, that as plants are not endued with volition and extensive locomotion, nor guided by instinct nor reason, they are subject to more regular and unalterable laws than the animal creation, at least than that portion of it which possesses those functions which have just been enumerated: their food is always placed within their reach, and they enjoy good health and arrive at perfection in their growth, independent of external accidents to which animals are equally liable, when they are situated where the soil contains those principles which are best adapted for the various purposes of their economy. The consideration of this fact suggests the questions,—What is the composition of soils? What part of soils is taken up as food by the roots of plants? To answer them has long employed the attention of the philosophical observer, and many and very various opinions have been given to the public; but it is only since modern chymistry made those discoveries which may justly be regarded as the most splendid triumphs of experimental Science, that any thing rational and satisfactory has been advanced. I will endeavour to lay before you as clear a view as I am able of the most probable conclusions which may be drawn from these opinions; and, in raising one corner of

the veil, remove much of the mystery with which, to ordinary observers, the subject appears to be enveloped. An investigation of this kind is as useful to the physician as to the botanist and agriculturist; for, many of the exciting causes of diseases, particularly of epidemics, are to be looked for in the nature of the soil and other local circumstances connected with the situations where they originate.

The fact cannot be too often repeated and impressed on your minds, that plants are living beings, possessed of powers which enable them to convert into their own material substance, matters of a nature apparently very different from it. Without keeping this in view, we should be forced to look for all the different productions of plants ready formed in the soil where they grow, and to suppose that these are simply taken up by their roots, and deposited in the different parts of the plant: an idea too incongruous to be admitted. On the contrary, they do not even take up those principles which are most abundant in the soil where they grow; but select peculiar parts of them, although these are not found, in general, forming in their uncombined state any part of the vegetable frame. Linnæus himself, however, I believe, and many others, have imagined, that every soil held in it something which is peculiarly the proper food of every kind of plant that can be

cultivated on it; and thus that poisonous plants extract something, on which their hurtful properties depend, which is not taken up by wholesome plants; or, that the secretions of plants do not vary in their qualities on account of the difference in the action of the vessels which secrete them; but owing to their components being already present in the soil. That this is not the case, however, has been clearly proved by the discoveries of modern chymistry, which have enabled us to analyse both the soil and the vegetables that grow upon it. By its assistance the mode of investigating the subject has been simplified, and more satisfactory results obtained.

The ultimate components of all the various substances produced by vegetables have been found the same, differing only in the quantity and the mode of their combination; and the parts of a soil which supply these have been found to be much fewer than was previously supposed. As we formerly asserted, when noticing the nature of sap, if this juice could be obtained near enough to the extremities of roots, or in the fibrils by which the soluble part of the soil is absorbed, then we should be able, by a careful analysis, to ascertain the real nature of the substances absorbed; and, by looking for these in soils, know how to supply their deficiency, or to diminish their superabundance. But as an accurate knowledge

of the components of sap cannot be obtained, owing to that fluid, as it advances, even in the vessels of the root, dissolving some already digested vegetable matter, which had been deposited there in the preceding autumn, we are obliged to form conclusions certainly not free from error; and to content ourselves with an approximation only to the truth. From the knowledge, however, which we do possess I will endeavour first to point out to you the known general components of natural soils; secondly, what part of these is taken up as food by plants; and thirdly, in what manner, and by what means, soils are improved and rendered more productive; or to investigate the general nature of manures.

Every soil fit for yielding nutriment to vegetables may be supposed to consist of earth, water, air, a small proportion of metallic oxyds, and decomposing vegetable or animal matters, in which are included salts, gases, and vegetable extracts.

Earth, which is the essential basis of all soils, is, as it is commonly spoken of, a compound of different earths; the most general of which are *Calcareous earth*, *Argillaceous earth*, *Siliceous earth*, *Magnesian earth*, and *Ferruginous earth.*

1. Calcareous earth comprehends lime, usually combined with carbonic acid, in the state of limestone, chalk, shells, and marl which is a mixture of carbonate of lime with clayey and

sandy matters; but lime is sometimes, also, found in combination with sulphuric acid, forming a substance called gypsum; and more rarely with phosphoric acid. When too much calcareous matter is contained in a soil, it is unfertile, owing to its absorbing moisture, and consequently remaining too dry. But the case is different when the calcareous matter is mixed with silica, for then the moisture absorbed remains in a free state, and not so united with the chalky matter as to disappear and be useless to plants. But the absorbing properties of all calcareous soils are not alike; and a great difference depends on the degree of comminution of the calcareous matter. Thus, 100 parts of calcareous sand retain, according to Professor Schübler's experiments, 29 parts only of water, whilst 100 parts of the same matter in the state of fine powder retain 85 per cent. In the first case, when calcareous earth and silica predominate in an arable field, they produce a hot and dry soil; when in the second, a moist and cold soil.

2. Argillaceous earth comprehends clay, which is generally mixed with siliceous sand and mineral substances, and is very retentive of moisture.

3. Siliceous earth is almost entirely composed of sand. The water passes so readily through it, that very little is retained for the pur-

poses of vegetation; and soils which contain much of this earth are, therefore, barren and unprofitable. In the form of sand it retains 25 per cent. only of water; while 100 parts of it, as it occurs with clay in an arable field, retain 280 per cent. of water.

4. Magnesian earth is not so commonly found as the earths we have already noticed. The magnesia it contains is combined with carbonic acid, and mixed with siliceous particles. It approaches nearest to the nature of the clayey earths in its power of retaining moisture; that power enabling it to retain $4\frac{1}{2}$ times its own weight of water. This renders it, when it predominates, very prejudicial to vegetation; while it increases, when added in moderate proportion, the fertility of a dry sandy soil.

5. Ferruginous earth consists of those oxyds of iron known by the names of ochres and pyrites mixed with siliceous matter. These oxyds, in particular the pyrites, when in any considerable quantity in a soil, if it contains little calcareous matter, are extremely injurious to vegetation. The pyrites is a compound of sulphur and iron, and is converted by exposure to air and moisture into sulphate of iron, which destroys plants by over-stimulating them.

Vegetable earths have the least specific gravity, and sandy soils the greatest, whether they be dry or moist: the vegetable earths contain, besides

vegetables in a state of decay, animal matter and a large proportion of salts, which are chiefly common salt, sulphates of magnesia and of potash, nitrates of lime, and carbonates of potash and of soda.

Such are the earths generally contained in soils: when any one of them abounds, the compound earth is named after this component; as for instance, a calcareous soil, an argillaceous soil, &c.

The principal difference which characterizes these various kinds of earths, is their power of retaining the next component of soils, WATER. Water, as forming a part of soils, is either chemically combined with the earth, or merely mechanically mixed with it, and retained in combination by cohesive attraction. In the former state it is of no use to vegetables, in the latter it is essentially necessary for their support. If the soil be not sufficiently retentive, the plant is starved, for nothing can be taken up from the earth which is insoluble; and, as we shall show afterwards, water itself is a principal part of the food of plants. If the soil be too stiff and retentive, the water remains upon its surface, and does not percolate to a sufficient depth to be applied to the roots: and if the vegetable be of a succulent kind, the herbaceous part remaining constantly surrounded with moisture has its vege-

tative powers weakened, and rots. This is particularly the case in winter; for, as the vital energy of the plant is then much lowered by cold, a disease of the vegetable takes place, similar to what happens in a leucophlegmatic state of the animal body, from which the plant rarely recovers. The most efficient soil, as far as water is concerned, is that which contains a due mixture of carbonate of lime, sand, and pulverized clay, with some vegetable or animal matters; and in which the materials are so mingled as to remain loose and permeable to the air. This soil is calculated not only to retain the water in proper quantity; but also to absorb it from the atmosphere, which is one great source of the supply that vegetables require: for water, as has been already remarked, is requisite for rendering the other matters in soils sufficiently soluble to be taken up by the roots of plants. All the earths are more or less soluble in water: thus lime is taken up readily in its pure state; and also if the water contains much carbonic acid in solution, when the lime is in the form of chalk, or a carbonate, in the proportion of about $\frac{1}{680}$ part of its weight. Clay is soluble in a minute proportion in rain water: silica even may be retained in solution by the aid of carbonate of potash; and in the minute state of division in which it is precipitated from an alkaline solution, it is soluble in

1000 parts of water: 2000 parts of pure water hold one of magnesia in solution.

Air is, also, a necessary component of soils. Atmospheric air is absolutely necessary, as we know, for carrying on the process of germination; the more pulverulent, therefore, the soil is, the more air it is capable of containing, and consequently is the better adapted for supporting vegetation. But a soil which is too sandy, the water not being retained, although it appears to be loose, yet does not contain so much air enveloped in it as is required; for the small particles of which it is composed apply more closely to each other, and lie in a smaller compass than the aggregated masses of a better soil, which touch at a few points only, and, therefore, leave more and larger interstices between them. When the soil is too retentive, the water which remains on its surface evaporates in summer, and depositing the clayey particles which it held suspended, a kind of paste is left, which hardening, by being baked, as it were, in the heat of the sun, no air can penetrate to the parts beneath it; nor can that which has been already used in the vegetative process, and which is unfit to carry it further on, escape: and we know that as atmospherical air is vitiated by the roots of growing plants, and during the germination of seeds, a constant renewal of it is requisite for supporting the vigour

of vegetables. It is the oxygenous portion of the atmospherical air contained in the soil, which is vitiated by the functions of the roots of plants. I shall have an opportunity of demonstrating to you the importance of this agent in the process of germination; and Sir H. Davy concludes, from an experiment on the vegetation of a Potatoe, in a given portion of atmospherical air, at a temperature of 59°, "that in cases in which shoots are thrown out from roots, oxygene appears to be uniformly absorbed, as in the germination of seeds *." Now, without stopping, at present, to inquire whether the opinion that it is absorbed in the process of germination be correct, it is evident that no accurate conclusions could be deduced from this experiment, because tubers perform nearly the same functions in evolving the buds on their surfaces, as the seed-lobes in the evolution of the embryon they enclose, during germination. To ascertain, therefore, the real manner in which the functions of the living root affect atmospherical air, I instituted the following experiment:—The roots of a Lilac, Syringa *vulgaris*, were partly laid bare, and one of them introduced into a cylindrical glass jar containing atmospherical air, freed from carbonic acid, and inverted in water. At the end of four days, du-

* *Elements of agricultural Chemistry*, 2d edit. p. 233.

ring which the thermometer had varied from 59° to 70°, the root was cut from the plant, and removed from the jar: scarcely any diminution of the air was perceptible; but lime-water became instantly milky on agitating it in the air of the jar, thereby demonstrating the presence of carbonic acid gas. The quantity of the gas was not ascertained in this instance.

The effect of oxygen gas, as a healthy stimulus to roots, was ascertained by Mr. Daniel Hill. He applied it to the roots of a plant of the Horseshoe Geranium, Pelargonium *zonale,* in a sickly state, and found that the plant soon revived, and grew with great vigour; and phials of oxygen gas inverted in water glasses, in which Hyacinth bulbs were placed, rapidly advanced the growth of the plants.

Soils contain CARBONIC ACID GAS also, independent of that which is formed by the vitiation of the atmospherical air. This is produced from the fermentation or decomposition of vegetable substances; and when it is not too abundant, it is useful by loosening the soil, by its expansion when first liberated: too much of it, however, checks germination and impedes the growth of plants.

When the vegetable matter which the soil contains putrefies, *carbonated hydrogen gas* is given out; and this is always present to a certain extent. It can be useful, like the former air, by the me-

chanical force only which it exerts in loosening the soil at the moment of its formation.

These decompositions, which are continually going forward in soils, evolve CALORIC; and this is retained sometimes very pertinaciously, and in such quantity as to be considered as a component of soils. It is certain that the earth is always warmer in summer than the surrounding atmosphere; but this is very variable near the surface; although, at a considerable depth, the temperature of the ground is almost all the same both in summer and winter. Soils however, which contain much siliceous earth, are not favourable to these decompositions; and in these, little caloric is accumulated. But independent of these decompositions, some soils are more readily heated than others; and portions of different soils heated to the same temperature cool with various degrees of rapidity: a stiff white clay soil is heated with difficulty; and, being usually very moist, cools rapidly; hence it is properly termed a cold soil: a chalky soil is heated with as much difficulty, but being dryer retains its heat longer; although it should be observed, that, of perfectly dry soils, those that are most readily heated by the solar rays likewise cool most rapidly. Sir H. Davy found "that a rich black mould which contained $\frac{1}{4}$ of vegetable matter," was heated by exposure to sunshine, from 65° to 88° in an hour; whilst

a chalk soil was heated to 69° only under similar circumstances. But when removed into the shade at 62°, the mould lost, in half an hour, 15°; and the chalk only 4°*. In many respects, therefore, the considering caloric as a general component of soils, is not too great a refinement to be adopted.

The last component of soils which we have to mention, has always been regarded as the most important of the whole. We allude to animal and vegetable matter in a state of decomposition, from which the black mould which constitutes the richness of soils is almost altogether formed. But the analysis of some of the most fertile soils has proved, that their fertility does not depend on the presence of a large proportion of these substances. Thus Sir H. Davy found that the soil of a very fertile field in East Lothian, contained nine parts only in the hundred of decomposed animal and vegetable matter; and a soil from the low parts of Somersetshire, long celebrated for yielding large crops of Wheat and Beans without manure, contained five parts of these principles only in the hundred†. It is indeed true, that the carbonaceous matter contained in plants can be derived most easily from decomposing animal and vegetable sub-

* *Elements of agricultural Chemistry,* 2d edit. p. 179.
† Ibid.

stances; but these also yield salts which prove highly stimulating to growing plants; and although plants seem to attain great bulk and vigour when much manure is applied, yet they are over-stimulated, and their growth is connected with disease, in the same manner as in an overfed and pampered animal. The natural state of both is altered; premature age succeeds, and death arrives long before the period when he should be naturally expected. Those plants also which are intended for the food of man and animals, when reared upon soil of the kind we are now noticing, yield less nutriment in the same bulk than that which more healthy plants yield, and it is also of an unwholesome kind. Upon the whole, we may truly assert that more harm is done by loading soils artificially with much animal and vegetable matter, than the natural deficiency of it in soils can occasion.

Such are the most general components of almost all soils; and as it is of much importance to know what is the composition of any soil, either in order to ascertain the probable causes of its fertility, with the view that less fertile soils may be rendered similar to it; or to estimate the value of ground with which we are unacquainted, and on which we have no opportunity of making experiments by rearing plants; we will endeavour to point out how this can be done.

When a Botanist examines a space of ground, he forms an estimate of the nature of the soil by observing the kind of plants, or weeds as they are termed, which it naturally produces, and dráws his conclusions from the knowledge he possesses of the relation which always subsists between the plant and the soil. If the plants are those which have much divided roots, he concludes that the soil is pulverulent and easily penetrated; but if the roots are thick and fleshy, that, as these require a humid soil, it is probable that it is damp and retentive. Some kinds of plants grow on one soil, but are never found on another; some require a large supply of carbonaceous matter, or a rich fertile soil; others, he knows, glean the little they require in the more barren, and soon die in richer spots. But the knowledge of the Botanist, although it is an accurate guide to a certain degree, in directing his judgment as to the value of uncultivated soils; and is valuable in preventing him from making bad speculations by introducing new objects of culture into a place which cannot admit of them; yet it is of little avail in examining soils under the immediate influence of cultivation. The experienced eye of the farmer supplies much of this defect. On too loose and poor soils the roots of barley and other grains are long, but the stems small and weak; but in a richer and more tenacious soil the roots are short, thick, and very

closely set with fibrils. The reason of these circumstances is, that the root shooting out towards the spots where the stimulus of nutriment is in greater quantity, exhausts the little nourishment it can obtain in adding to its length, and, therefore, an insufficient supply is left for the stem and leaves; but in richer soils the whole of the fibrils being surrounded by nutritious matter, a greater quantity is actually taken up by a much smaller surface of roots, and supplies more freely the herbaceous parts of the plants.

To ascertain the real nature of soils, chymistry must lend its assistance; and this mode of examination is undoubtedly the most certain. Sir H. Davy has, however, justly remarked, "that the results of analyses considered as affording indications of fertility must "necessarily differ according to the variations of "climate, situation, and other circumstances. "Thus, the power of soils to absorb moisture "ought to be greater in warm and dry countries "than in cold and moist ones, and when the "quantity of fine argillaceous earth they contain "is larger. Soils likewise which are situated on "declivities, ought to be more absorbent than "those in the same climate situated on plains and "valleys. The productiveness of soils must like- "wise be influenced by the nature of the subsoil, "or the earthy and stony strata on which they

"rest. Thus, a sandy soil may sometimes owe its "fertility to the power of the subsoil to retain "water; and an absorbent clayey soil may oc-"casionally be prevented from being barren, in a "moist climate, by the influence of a substra-"tum of sand or gravel." Notwithstanding these obstacles, however, to the formation of perfectly correct results in the chymical analysis of soils, still, by observing the circumstances which may thus alter the properties of a soil, and making allowances for them, we are enabled by its means to form a tolerably accurate notion of the comparative value of soils.

When any soil is to be examined, the specimen, which should never be less than three or four hundred grains, must be spread out to dry, and then carefully weighed. As it is of importance to discover the physical properties of a soil prior to its analysis, for these direct in some respects the experiments that may be necessary, the specific gravity, colour, and consistence of the specimen should be next ascertained. If a phial, which holds 400 grains of water, be half filled with that fluid and the soil introduced until the liquid rises to the mouth, and then weighed, the difference between the weight of the soil and that of the water (which is known) will give the specific gravity of the soil. Thus, if the phial filled as described gains 200 grains in weight, the gravity of the soil will be 2, or double that of water

which is the standard; and, if it gain 165 grains, it will be 1.825, water being 1.000 *. A red or yellow colour indicates the presence of iron; and the scratching glass when rubbed upon it, that of silex. A given portion of the soil is next to be submitted to a degree of heat sufficient to dissipate the whole of the water it contains without consuming the vegetable and animal matter, or extricating the carbonic acid gas from the lime and other calcareous substances it may contain. The temperature should not exceed 300° Fahr.; or a piece of wood may be laid in the dish in which the process is conducted, and whenever it "begins to be "charred, the process must be stopped." The specimen should now be again weighed, and when in 400 grains the loss is 50, the soil may be regarded as highly absorbent and retentive of water, and to contain either much decomposing organic matter, or a large proportion of clay; but when the loss is under 20, it cannot be considered as either very absorbent or very retentive, and is probably formed chiefly of sand. After bruising in a mortar the portion thus treated, the larger stones, gravel, and vegetable fibres should be separated by the sieve, and their weight noted down.

The sandy matter, which is insoluble, is easily separated by boiling the specimen in three or

* *Davy's Elements of agricultural Chymistry.*

four times its weight of water, and when "the "soil is broken down and the water cool, by "agitating the parts together and suffering them "to rest for a minute or two, and then pouring "off the water with what it holds suspended in it. "The repetition of this elutriation will at length "free the sand from all the other substances, and "that being thrown on a filter and weighed, the "result will give the quantity of uncombined si-"lex in the soil." The water of lixiviation must be preserved, as it will be found to contain the saline and soluble animal and vegetable matters, if any exist in the soil.

Calcareous matter is discovered by adding to the portion finally deposited from the water of lixiviation a quantity of muriatic acid "twice the "weight of the earthly matter; but diluted with "double its volume of water:" an effervescence is occasioned if lime, or any other calcareous substance, be present, and muriate of lime is formed; to separate which, and ascertain the quantity of the lime, the whole should be thrown into distilled water. The water dissolves the muriate of lime; and the solution separated by filtration being evaporated to a certain degree, carbonate of soda is next to be added to precipitate the lime. The weight of the precipitate, after it is washed and dried, gives the quantity of calcareous matter contained in the soil. If magnesia be present, it

is known by the same process; but the precipitate must be washed with diluted sulphuric acid, by which means the lime is formed into insoluble gypsum, or sulphate of lime, and the magnesia into soluble Epsom salt. These salts can be easily separated by filtration and crystallization; and by knowing the quantity of each thus formed the real quantity of lime and magnesia is ascertained by the following rule:

100 parts of gypsum contain 48 of acid, 34 of lime, and 18 of water.
100 parts of Epsom salt... 33 ..... 19 ........ 48

The organized matter, or the animal and vegetable substance, is known by strongly igniting what remains of the specimen, after the calcareous matter is separated, in a crucible over a common fire, until no blackness remains in the mass: the loss of weight denotes the quantity of organic matter. The clay is ascertained chiefly by sight and touch; and the ready-formed salts by the evaporation of the washings of the specimen and crystallization.

Such is the method of ascertaining the principal contents of any soil; and its value may be computed by the knowledge we possess from the experience of agriculturists, as to the capacities of the different earths for retaining water and air. When the examination is completed, the products should be numerically arranged, and if their

quantities, added together, nearly equal the original quantity of the specimen, the analysis may be considered as accurate. Many little niceties of manipulation are necessary to be attended to; but, for these and other particulars requisite to be examined when the analysis is required to be very accurate, I must refer you to Sir H. Davy's admirable work on Agricultural Chymistry, which is the source of much of the information contained in this Lecture. Let us now examine in what way the components of a soil affect plants; and which of these are taken into the vegetable system.

The principal matter, undoubtedly, that plants take up from the soil is water; and from the results of several experiments in rearing plants in pure water, this fluid has been by many supposed to be the only food of plants. But when these experiments were repeated with greater care, and the water employed to moisten the pure sand in which the seeds were planted was distilled, the plants thus raised were found not to have gained any augmentation of vegetable matter; and seldom or never perfected their seeds, although they flowered. In some cases, however, a small addition of vegetable matter had been gained. We have already ascertained that the elements of vegetable matter are carbon, hydrogen, and oxygen; and as we know also that water is composed of hydrogen and oxygen, we can easily believe that

these two elements can be obtained from the decomposition of this fluid by the powers of the plant; but, without the presence of any soil, whence is the carbon, which is required for the formation of the additional vegetable matter, obtained? It has been suggested that the air is capable of supplying this, and that the quantity of carbonic acid gas it contains, although small, is never wanting. It is, however, possible that it may have been afforded by the water; for although it was distilled, yet, as Sir H. Davy's experiments have proved, distilled water may hold many substances in solution, and these never can be completely separated from it. But, if we even allow that water and air are the only sources from which the vegetable matter thus gained could be derived, we also know that many plants cannot be supported in this manner, and yet a direct supply of nutritious matter is indispensable to their growth and existence. Every farmer knows the fact, that many plants will grow only in certain soils; and his art consists in supplying to the natural soils that part which is most essentially necessary for their support. As we have proved that the components of all vegetable matter are carbon, hydrogen, and oxygen, we must look for the supply of these ingredients in the soil: and it is from water and decaying organic matter that they are undoubtedly obtained. From this

matter then the carbon is supplied; and as water only, and those substances which it can hold in solution, can be absorbed by the mouths of the roots of plants, the carbon which is contained in the soil, separated from vegetable and animal matters by decomposition, must be dissolved in the water in order to be taken into the system of the plant *; and it thus becomes their proper food.

If this view of the subject be correct, the art of the husbandman and horticulturist must consist in applying those substances to the soil which will promote the growth of plants without overstimulating them. The different matters known under the title of manures, which are employed for this purpose, must act in four ways to produce the effect required. 1. They must render the soil of that consistence which will enable it to retain a sufficiency of water; but not too much. 2. They must render it pulverulent to admit the roots of the plants to permeate, and spread freely in it. 3. They must enable it to admit and retain air in its interstices: and, 4. fit it to form carbon, and afford healthy stimuli to the vegetable irritability. The importance of a finely pulverized

* The pores in the fibrils of plants are so minute, that a powerful microscope is required to discover them; the extreme division, therefore, of insoluble matters, which pass into the vegetable system may readily be conceived.

soil was first pointed out by Jethro Tull, in 1733; but although his ideas on this subject extended to an absurd degree, and led him to form a theory of vegetation altogether mechanical, yet the direction of the agriculturist to the importance of pulverization, has been productive of the most beneficial results. It allows of the easy extension of the roots of plants, admits a necessary supply of air during the process of germination, and assists those decompositions which are requisite for rendering manure useful.

The first place among the substances fit to answer the purposes already specified, is certainly due to lime. This substance acts upon soils either mechanically or chymically; and on the plants it acts physiologically. When in the state of a carbonate, or united with carbonic acid, it is added to clayey soils, it acts mechanically by rendering them more free, loose, and pervious both to air, moisture, and the roots of plants: it acts chymically when it is deprived of carbonic acid or is in the caustic state by destroying worms, and other insects hurtful to young vegetables; and, by quickening the decomposition of their dead bodies, renders them useful to vegetation. In either state it neutralizes acids, and decomposes salts of iron and other injurious saline matters often contained in soils; and by the healthy stimulus which it affords when in the state of quicklime it invigorates

vegetation both in young and mature plants. Lime also hastens the decomposition and solution of vegetable matter; and has been long known as a most useful manure when applied where half-decomposed vegetable matter abounds, as for example, in peat soils. The best corrective, therefore, for ground that has been too much dunged is lime: and peat mosses *, which consist of vegetable substances, the decay of which has been suspended by the formation of a peculiar acid in them, are rendered arable and highly fertile by a proper use of lime. In this operation the lime is combined with the acid contained in the moss, and also with carbonic acid, and remains as a component of the newly-formed soil. Every kind of quicklime, however, does not answer for manure, and particularly that which abounds with magnesia; for although magnesia, when united with carbonic acid, is a useful ingredient in a soil, yet in its uncombined state, or as calcined magnesia, which is that in which it must be, when magnesian limestone is burnt into quicklime †, it is

* Peat appears to be formed by the occasional flooding of places where successive generations of vegetables have grown, and been allowed to decay undisturbed, until at length the decomposition is stopped by the water not passing off. The soil is thus rendered spongy, and an acid is generated which prevents the farther production of vegetation.

† Magnesian limestones are easily distinguished by their dissolving very slowly in acids; and by their rendering weak solutions of nitric acid turbid.

injurious to plants; as proved by the experiments of Mr. Tennant. When, however, even the best quicklime is too freely used, it becomes hurtful by over-stimulating the growing plants; and, therefore, the more frequent and small application of it is preferable.

It would be out of place in this Lecture to notice all the substances used as manures; the object of all of them is either to alter the retentive quality of the soil, or immediately to supply carbonaceous matter to the plants. For these purposes, as occasion has required, clay, brick rubbish, limestone, marl, chalk, sand, gravel, have been employed as mechanical means *; salts of various kinds as stimulants; and soot, ashes, and dung, as affording the proper nutriment of plants. That salts are taken up ready formed from the soil by vegetables is pretty certain; Du Hamel and Cadet having established the fact, that, if the marine plants, which yield soda while they grow near the sea, be removed to inland situations, they gradually cease to yield soda, and at length potash only is obtained from their ashes †. We shall merely

* Wet clay can be burnt to powder if put into the fire uncompressed, and consequently prove useful as a manure. *Memoirs of Lord Kames. Appendix*, p. 224.

† Even earths, although they cannot be converted into organized matter, yet, when in a state of extreme division, are taken up by the roots of plants, and deposited in various parts of the vegetable system. Thus silica is so abundant in the

notice, with regard to dung, that when it is completely rotten it does not afford much soluble carbon, owing to its having become as it were oxydized and the carbon being converted into a real charcoal; other principles also, such as carbonic acid and ammonia, useful both as stimuli and nutriment to plants, are dissipated during the violent fermentation, which is requisite to reduce dung into this state. Fresh dung, or that which is not completely rotten, on the contrary, benefits not only the present crop but several subsequent ones, as its good effect continues as long as the process of decomposition goes on. That many of the good effects of fresh dung depend on the extrication of heat is evident; and I am inclined to think it is to this agent, chiefly, that must be attributed the great superiority of the green vegetable matter used as manure, in some experiments detailed by Mr. Knight, in the Horticultural Transactions *; and not, as that gentleman supposes, to the nutriment of vegetables being more easily assimilated into the substance of the living plant, the less it has passed from the state of living vegetable matter.

Such are some of the facts relative to soils,

epidermis of the Equisetum, Mare's Tail, that it is used by cabinet-makers for polishing furniture: and it is also found composing part of the epidermis of Wheat, Oats, and some other grasses.

* Vide Volume 1st.

manures, and the food of plants, which the consideration of the structure and the use of roots to the plant have suggested. It may be thought that I have travelled out of the proper path, in giving even the slight view of them which I have attempted; but my object is to excite those who have leisure and opportunity to examine more closely a subject so intimately connected with the prosperity and happiness of our country, and the most essential interests of the human race.

We have noticed the importance of the root as a vegetable organ, but it is not less interesting as yielding medicinal agents, supplying dying materials, and affording an abundant store of food for man and other animals. Many of the secreted juices of plants which are deposited in the roots, particularly when the stems annually decay, possess medicinal properties. Indeed, there is scarcely one of the divisions of the Materia Medica in which some of the roots, or their appendages, are not to be found. Thus, among the EMOLLIENTS we find the roots of Marsh Mallow, Althæa *officinalis*, of Sarsaparilla, Smilax *sarsaparilla*, and of Liquorice, Glycyrrhiza *glabra*, yielding demulcent and saccharine mucilages. Among STIMULANTS, which produce their specific action on particular organs, the bulbs of the white Lily, Lilium *candidum*, and of Garlick, Allium *sativum*, may be employed to affect the skin as rubefacients and

epispastics; the roots of the Florentine Iris, Iris *Florentina,* and of White Hellebore, Veratrum *album,* as errhines, to stimulate the olfactory nerves and promote a discharge from the nostrils; while Pellitory root, Athemis *Pyrethrum,* and the roots of Mezereon, Daphne *Mezereon,* Horse-radish, Cochlearia *Armoracia,* and Cuckow-pint, Arum *maculatum,* contain acrid matters which, when the roots are masticated, stimulate the salivary glands, or act as local sialagogues. From Cephælis *Ipecacuanha* we obtain our most useful emetic; and several other roots, as those of Viola *parviflora,* V. *Ipecacuanha* and V. *Calceolaria,* Cynanchum *Ipecacuanha* and C. *tomentosum,* Dorstenia *Brasiliensis* and D. *arifolia,* possess also useful emetic properties. The best Cathartics are obtained from roots, as, for example, those of Rhubarb, Rheum *palmatum,* of Jalap, Convolvulus *Jalapa,* Scammony, Convolvulus *Scammonia,* Bryony, Bryonia *alba;* and that favourite of the ancients, black Hellebore, Helleborus *niger.* The roots of Burdock, Arctium *Lappa,* Eryngo, Eryngium *maritimum,* and Dandelion, Leontodon *Taraxacum,* are diuretic, or augment the urinary discharge:—as remedies possessing the power of increasing the natural exhalation by the skin, or diaphoretics, we may mention Snakeroot, Aristolochia *serpentaria,* the roots of Contrayerva, Dorstenia *Contrayerva,* and of Mountain

Arnica, Arnica *montana;* and as expectorants, Seneka-root, Polygala *senega,* and the bulb of the Squill, Scilla *maritima.* That division also of the class of stimulants, which comprehends those remedies that exert a general operation on the system, is equally rich in roots: thus, among the permanent stimuli we find the roots of Common Avens, Geum *urbanum,* Bistort, Polygonum *Bistorta,* Tormentil, Tormentilla *erecta,* and of the Water Dock, Rumex *aquaticus,* employed as astringents; and those of Sweet Flag, Acorus *Calamus,* Ginger, Zingiber *officinale,* Sweet Fennel, Anethum *Fœniculum,* garden Angelica, Angelica *archangelica,* Zedoary, Curcuma *Zedoaria,* Yellow Gentian, Gentiana *lutea,* Elecampane, Inula *Helenium,* and Calumba, as aromatics and tonics. Among the diffusible stimuli the root of Thorn Apple, Datura *stramonium,* is narcotic, and that of Valerian, Valeriana *officinalis,* antispasmodic; whilst the bulb of Meadow Saffron, Colchicum *autumnale,* besides acting as a cathartic, exerts a directly sedative effect on the nervous energy.

As agents in the art of dying, the chief colour that roots impart is red; in producing which, those of Madder, Rubia *tinctorum,* and of Alkanet, Anchusa *tinctoria,* are of great importance: various shades of this colour are also obtained from the roots of several species of Bed-straw, Galium; and a very beautiful, but less permanent

tint, is yielded by the slender roots of Indian Madder, Oldenlandia *umbellata.* The proper juice of the Blood-root, Sanguinaria *Canadensis,* is bright orange, and that of the Celandine, Chelidonium *majus,* is yellow; but I am not certain that either of these have been employed as dye stuffs.

But it is in furnishing food that man has most successfully exerted his ingenuity on these vegetable organs. The roots of many plants, which in a state of nature are small, have been enlarged by cultivation, and rendered capable of yielding a considerable supply of nutritious aliment; for example, the Carrot, the Turnip, the Beet, and the Parsnip. Roots that are acrimonious and poisonous when raw, are so altered by the art of cookery, as to become mild, nutritious, and wholesome food, owing to heat destroying the acrimony upon which their injurious properties depend: and, even by simple elutriation, one of the most virulent of poisonous roots, that of Jatropha *manihot,* is converted into Tapioca, a mild fecula, well known for its nutritive qualities, and universally employed as an article of diet in convalescence and by persons of delicate habits. By similar means many other roots, also, which are now regarded as hurtful, might be rendered inert; and large additional supplies thus afforded to the vegetable stores already selected for the subsistence of the animal creation.

# LECTURE VI.

THE STEM—ITS DIRECTION—DIVISIONS AND BRANCHING—COVERING—COLOUR—FIGURE. CLASSIFICATION OF STEMS.

HAVING finished the consideration of the root, I have now to direct your attention to the two next divisions, in our enumeration of the parts of the plant, the *stem* and the *branches*. These organs are generally above the surface of the ground, and consequently in sight: I therefore propose, in order to methodize our investigation, to view them in the first place, simply as they are presented to the eye, in the entire plant; then more closely as regards those external properties on which Botanists have founded their classifications of them; and lastly, to demonstrate the anatomy of their internal structure: thus preparing you to understand more readily their physiology. You should, however, be previously informed, that the stem and branches are organs not essential to the vegetable structure, although they are so to the plants in which they are found; for, independent of some Lichens, and many species belonging to those tribes of vegetables which Botanists have denominated imperfect, they are never present in many

other plants, the foliage and fructification of which spring directly from the root or some of its appendages; as, for example, the Meadow Saffron, Colchicum *autumnale*; stemless Asphodel, Asphodelus *acaulis*; and stemless Artichoke, Cynara *acaulis*, &c. These plants are nevertheless perfect, and capable of performing all the functions necessary in their economy; the term imperfect, as I formerly observed, being applicable to individuals only, in which the organs necessary for carrying on the functions of the plant and providing for the continuation of the species are defective.

Under the general name of stem is comprehended that portion of a plant which, proceeding from the upper part of the root, affords support to the branches, the leaves, and the fructification *. If we take a view of the vegetable kingdom, we are struck with the wonderful diversity in the size, direction, form, and exterior aspect of this part of plants. How great is the difference in strength, for example, betwixt the delicate

* " *Truncus* multiplicat herbas, et immediate a radice " ad fructificationem ducit, vestitus foliis, terminatus fructifi- " catione." *Phil. Bot.* § 81.

" *Truncus* folia et fructificationem profert." Ibid. § 82.

" *Tige* support principal des parties du végétal qui s'élevent " au dessus de terre." *Mirbel*, *Elemens*, *&c.* p. 622.

Willdenow denominates it the stock *(cormus)*. *Principles of Botany*, § 15.

thread which supports the flower of the bending Hairbell, and the rigid trunk of the majestic Oak! and in position and altitude, betwixt the creeping Bramble and the towering Palm, rising to the height of upwards of two hundred feet! Some of the climbing plants have been found, when untwisted, to be five hundred feet in length: and Captain Cook observed, that in parts of the ocean, where the soundings were upwards of thirty fathoms, the sea-weed stretched in a direct line from the bottom to the surface of the waves. The diversity in the thickness or diameter of the stem is not less remarkable. In the Club-rush, Scirpus *capillaris*, it is quite a hair, while Swilcar Oak, on the contrary, is thirteen yards in circumference round the base of the trunk, and eleven yards at the height of four feet from the ground: in Chesnut trees it has been known to acquire, even in Great Britain, forty feet in circumference; and we are informed that the trunk of the Calabash tree, Adansonia *digitata*, which grows on the coast of Africa, although not more than twelve or fourteen feet in height before it branches, is frequently twenty-seven feet in diameter*. Such is the amazing extent to which the stem may attain;

* "The branches of the Adansonia, which are numerous "and thick, extend from thirty to sixty feet out from it in "all directions; and the hollow trunk is often the dwelling of "several negro families." *Fam. des Plantes, Pref.* ccxii.

but the necessities of men seldom permit trees to arrive at their utmost growth; and, to quote the words of an elegant writer, "Nature preserves her "magnificence in those places only, where man "cannot assert his empire."

Although almost * all stems rise out of the ground, yet, no minute inspection is required to perceive that they do not all assume the same *direction.* Some stand erect, elevating their foliage in the air; others approach to the perpendicular only; some, too lax even to support their own weight, raise themselves by twining around those which are more rigid, or climb by the aid of various appendages; while others again lie prostrate, or creep along upon the surface of the earth. Each of these peculiarities has been noticed by Botanists, and named. A stem is said to be,

1. ERECT *(erectus, verticalis, perpendicularis),* when its position forms nearly a right angle with the surface of the soil from which it rises, provided that surface be almost parallel to the horizon. There are four varieties of the

* I use the word almost, because many plants that appear to be stemless, have a cylindrical caudex rising from the real root, which is very deep in the ground, to the surface of the earth, where it gives off a tuft of leaves and flowers; as in common Mousetail, Myosurus *minimus.* This portion does not perform the office of a root, and, therefore, it may be considered as participating of the nature of a stem.

erect stem, derived from the character of the line it produces from the base to the apex. An erect stem is

a

b

*a.* Straight *(strictus, rectus, rectilineus)* (fig. *a*), when it has no natural curve in any portion of its length, however thickly branched it may be; as, for example, that of the Silver Fir, Pinus *Picea* (*a*), among trees; and of Spear Mint, Mentha *viridis,* among herbaceous plants.

*b.* Flexuose (*flexuosus)* (fig. *b*), when it is naturally a regular zigzag, so as to form alternate obtuse angles from right to left, and from left to right *; as in Box-leaved Staff-tree, Celastrus *buxifolius* (*b*); and common Birthwort, Aristolochia *Clematitis.*

*c.* Tortuous *(tortuosus),* when it is curved or writhed in different directions, but not regularly as in the flexuose stems.

* "*Flexuosus,* secundum articulos horsum vorsum flexus; *Ptelea.*" *Phil. Bot.* § 82. 4.

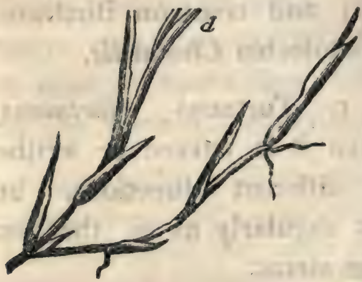
*d.* Nodding *(nutans, cernuus)* (fig. *c*), when near the summit only it takes a direction more or less towards the horizon, the lower portion being quite erect; as in the Cedar, Pinus *Cedrus*, and Solomon's Seal, Polygonatum *multiflora* (*c*).

c

2. Oblique *(obliquus)* is the term employed to designate the elevation of a stem, the direction of which is diagonal to the plane of the horizon. There are three varieties of the oblique stem. It is said to be

*a.* Ascending *(adscendens)* (fig. *d*), when its lower portion forms a curve, the convexity of which is towards the earth, or rests upon it, and the summit rises perpendicularly; as exemplified in many of the Grasses (*d*); in Common Toad Flax, Thesium *linophyllum*; common Clover, Trifolium *pratense*; small Carex, Carex *dioica*, &c.

d



*b.* Declined *(declinatus, reclinatus)*, when the lower part of the stem rises obliquely from the ground; but the upper bends towards it, forming an arch *; as in that of the Fig-tree, Ficus *carica.*

*c.* Incurvated *(incurvus)*, when the stem rises and bends as in the former; but with the apex turned inwards, as in that of the common Bramble, Rubus *fruticosus.*

3. Supported *(fulcratus)* (fig. *e*). A supported stem appears as if it were propped by a number of other stems that surround it, inclining towards each other, at their summits, until they seem engrafted into the base of the stem which they support: as in the Mangrove, Rhizophora *mangle* †.

*e*

This curious appearance is occasioned by the

* " *Reclinatus*, arcuatim versus terram; Ficus." *Phil. Bot.* § 82. 6.

† This species of Rhizophora is found in Asia, Africa, and South America, growing in marshy and flooded flats, in creeks, and at the mouths of rivers.

original trunk sending off two distinct kinds of branches: those at the summit bear leaves and the fructification, while the lower are leafless, and bend down until they touch the ground, in which they root, and are changed into real stems.

4. CLIMBING STEMS *(scandentes)* are those which, being too delicate and flexible to support themselves, require the aid of some perpendicular body to enable them to elevate their foliage and fructification in the air; and this is accomplished by one or other of the following means:

A stem is denominated

*a.* Twining *(volubilis)*, when it winds itself spirally round any other plant or upright slender body *. This motion is performed invariably in one direction by all the plants of the same species; and is so natural to them, that if it be forcibly reversed, the plants will untwine themselves, and again assume the direction peculiar to their species. When the twining is from left to right, or following the apparent motion of the sun, as in Woodbine, Lonicera *Periclymenum;* or the Hop, Humulus

* " *Volubilis* spiraliter adscendens per ramum alienum.

" Sinistrorsum ☾ secundum solem vulgo: *Humulus*, " *Helxine*, *Lonicera*, *Tamus*.

" Dextrorsum ☽ contra motum solis vulgi; *Convolvulus*, " *Basella*, *Phaseolus*, *Cynanche*, *Euphorbia*, *Eupatorium*." *Phil. Bot.* § 82. 5.

*lupulus* (fig. *f*, 1), it is termed *sinistrorsum*;


and when it takes the opposite direction, or from right to left, as in the Scarlet Bean, Phaseolus *multiflorus*, the Great Bindweed, Convolvulus *sepium*, or smooth Periploca, Periploca *lævigata* (fig. *f*, 2), *dextrorsum*. The cause of this spiral motion of twining stems I will endeavour to explain, when we inquire into the movements of plants.

*b*. Radicating *(radicans)*, when it sends forth from one side short, fleshy, root-like fibres, by means of which the plant elevates itself on the perpendicular surfaces of walls and rocks; as in the Ivy, Hedera *helix*; (fig. *g*, 1. see p. 250), Ash-leaved Trumpet-flower, Bignonia *radicans*, &c. In general


these root-like appendages insert themselves into the crevices of the wall or rock, on the face of which the plant climbs; but, in some instances, they operate like the feet of flies, and of those lizards that have the power of running up smooth perpendicular walls and along the ceilings of rooms; or rather like the suckers which boys employ for lifting stones, and which adhere, by the closeness of their application preventing any air from being interposed between them and the spot on which they are applied. Some Botanists imagine that these caulinary radicles differ materially from the roots thrown out by the stems of creeping plants; and that they do not imbibe nourishment*; but in my opinion the

* Such is the opinion of Sir J. E. Smith (see *Introd. to*

difference is more imaginary than real; for, if they cannot enter into crevices, they stretch down towards the earth to a considerable extent; for if a shoot of Ivy happen to lie upon the ground, the radicles, which would have remained short had it ascended the wall, extend into real absorbing roots (see fig. *g*, 2, *a b*). They are, also, always protruded from that side of the stem which is farthest from the light and air, and consequently the moistest; and, thence, the opinion that they do not absorb is at least problematical.

*c.* Climbing *(scandens)*, when it is furnished with tendrils, which are filiform spiral appendages, that twine round the branches and twigs of upright plants; which are thus enabled to elevate their foliage and fructification: as in the Vine, Vitis *vinifera*, and all the species of Passion-flower, Passiflora, &c. In some climbing plants, which are not furnished with tendrils, as for instance, purple Virgins Bower, Clematis *viticella*, and Bittersweet, Solanum *Dulcamara*, the petioles or

*phys. and system. Botany*, p. 118). Linnæus, on the contrary (*Phil. Bot.* § 82, p. 8), seems to have confounded the creeping with the climbing radicating stems, in the following definition: " *Repens* radiculas hinc exserens procumbendo; *Hedera*, " *Bignonia*."

footstalks of the leaves serve the purpose of tendrils, and twine round the props upon which the plants climb.

5. Decumbent *(decumbens)* is a term given to a stem when it rises a little upright at its base; but has its upper portion bent down towards the ground, so that the greater part of it is procumbent.

6. Procumbent *(procumbens, prostratus, humifusus)* implies that the stem, being too weak to support itself, lies flat on the ground *; as in Bearberry, Arbutus *uva ursi*, Scarlet Pimpernel, Anagallis *arvensis*, &c. Many procumbent stems throw out roots from the under surface, thereby receiving nourishment in their progression; and this circumstance constitutes a variety, which has been denominated

*a*. Creeping *(repens)* (fig. *h*). It denotes

*h*

* " *Procumbens*, horizontaliter supra terram." *Phil. Bot.* § 82, p. 7.

that the stem extends horizontally, or on the surface of the ground, and sends out roots from below; as in lesser Periwinkle, Vinca *minor* (*h*), and Ground Ivy, Glechoma *hederacea*. Linnæus, Sir J. E. Smith, and some other authors, describe another variety of the procumbent stem under the term trailing or sarmentose *(sarmentosus*)*: but the sarment is, properly speaking, not a stem, but merely a runner which performs the same functions as the underground runners, to which pendulous tubers are attached. It is, in fact, a vascular cord, intended to place the lateral progeny of the plant at a convenient distance from the parent, and to convey nourishment to the offset until such time as it takes root and is capable of supporting itself. It is at first sent off from the neck or collet of the root; but, afterwards, it gives off itself roots at the points where the offsets spring; and, as the manner in which this is effected varies, it is of different kinds; but these shall be demonstrated when we investigate the appendages of the stem. The swimming stem

* "*Sarmentosus*, repens, subundus est." *Phil. Bot.* § 82. 9. "Sarmentosus, trailing. A creeping stem, barren of flowers, "thrown out from the roots for the purpose of increase, is "called sarmentum or flagellum, a runner." *Smith's Introduction*, &c. p. 120.

(C. *natans)* has a much better claim than the sarmentose to be ranked as a variety of the procumbent stem, as it is a real stem, and lies floating on the surface of the water, throwing out radicles from the under side: the Floating Club-rush, Scirpus *fluitans*, is an example. The term *natans* for denoting this position of the stems of aquatics is of importance in a systematic point of view, and is used in contradistinction to *sunk (demersus)*; which implies that the stem lies below the surface, as in common Hornwort, Ceratophyllum *demersum.*

Besides the diversity which prevails in the position or direction of the stems, we perceive, in glancing the eye over the vegetable kingdom, that they present much variety, also, with respect to general form. Thus, some are simple or undivided, while others are divided and subdivided into very minute ramifications.

1. The UNDIVIDED or SIMPLE stem (C. *simplex)* consists of one piece only, without any branches bearing leaves; although the flower-stalk may be divided; as exemplified in knotty-rooted Figwort, Scrophularia *nodosa.* When, however, there is no division even of the flower-stalk, but the whole stem is one rod or column from the base to the summit, and is terminated by a single flower, or a simple spike, it is

then termed very simple *(simplicissimus)*; as in Bistort, Polygonum *bistorta*, the Date Palm, Phœnix *dactylifera*, &c.

2. The DIVIDED stem, owing to the parts into which it divides being termed branches *(rami)*, is denominated branched *(ramosus*)*; and the manner in which this is effected produces diversities in the general aspect of plants of great importance to the systematic Botanist. It affords, also, a kind of physiognomical character to each species, by which it is immediately recognizable to the eye of observation; and the perceiving this character, and retaining a clear impression of the perception in the memory, ought to be strictly attended to by the student. It affords him a sure guide to the more particular examination of vegetable nature; associating the minute characteristics of each species so closely with its general features, as to call those up rapidly in the memory, whenever these present themselves either to the eye or the imagination; and, in Botany, you will soon be convinced how essential it is to fix, in as practical a manner as possible, every impression which the examination of plants can make on the mind. The greater masters of the old schools of painting were fully aware of the importance of studying the physio-

* "*Ramosus* est ramis lateralibus instructus." *Phil. Bot.* § 82. 21.

gnomy of plants, especially of trees; and they carefully transferred it to their canvass. Thus you can recognize in their landscapes, as in nature, a Poplar, a Willow, the Cedar, an Elm, an Oak, or any other tree; whereas, the general term trees is sufficient to describe the foliage, which crowds in confused masses the pictures of inferior artists.

The branches are evident divisions of the principal trunk; yet, in the majority of instances, the stem can be traced, as it rises amidst these divisions, from the base to the apex; but as it is, also, in some plants entirely lost, Botanists employ distinct terms to designate these opposite states: thus, *continuus* is used for the former, and for the latter *decompositus*. The branching of a stem admits of several varieties, each of which requires to be noticed. It is said to be

*a.* Slightly branched *(subramosus)*, when the number of divisions are comparatively few.

*b.* Much branched *(ramosissimus)*, when not only the greater divisions are numerous, but these are again divided and subdivided without order *; as in the Elm, Ulmus *campestris*; the Gooseberry-bush, Ribes *Grossularia*, &c.

* "*Ramosissimus* ramis multis absque ordine gravidus." *Phil. Bot.* § 82. 2.

Linnæus and some others employ the term proliferous *(prolifer)* to denote a modification of the much-branched stem, in which the new branches shoot out only from the summits of the former ones *, as in the Scotch Fir, Pinus *sylvestris:* but, as Sir J. E. Smith remarks, the term is obsolete, and seldom used.

*c.* " Abruptly branched *(determinatè ramosus)*, when each branch, after terminating " in flowers, produces a number of fresh shoots, " in a circular order, from " just below the origin of " those flowers; as in naked-flowered Azalea, Azalea *nudiflora*, and many " of the Cape Heaths †."

*i*

*d.* Forked or dichotomous *(dichotomus)* (fig. *i*), when the divisions and subdivisions are, throughout, in alternate bifurcations; as exemplified in Corn Salad, Valeriana *locusta*, Petty Spurge, Euphorbia *peplus*, and

* " *Prolifer* ex apicis centro emittens tantum ramos; " *Pinus*." *Phil. Bot.* § 82. 28.

† Smith, from whom this definition is borrowed, says that the term *determinatè ramosus* occurs frequently in the later publications of Linnæus, particularly the second *Mantissa;* but that he has not any where explained its meaning. *Introd.* p. 122.

forked Marvel of Peru, Mirabilis *dichotoma:* but when, instead of being bifurcated, the divisions are trifid, the stem is then said to be *trichotomous;* as in common Marvel of Peru, Mirabilis *Jalapa.*

The BRANCHES themselves, whatever may be their numbers or divisions, vary considerably with respect to their situation on the stem; the direction they assume relatively to it; and their strength, or the power they possess of supporting their own weight: and these diversities are seized by systematic Botanists in forming the characters of species.

* *In situation.*

Branches may be either opposite, or alternate, or scattered. They are said to be,

1. OPPOSITE *(oppositi),* when one branch stands on the opposite side of the stem to another, and their bases are nearly on the same plane. Besides this situation of branches, to which the term *opposite* is especially applied, the two following may be regarded as varieties of it:

*a.* Verticillated *(verticillati),* when the stem is the centre of a number of branches proceeding from it like rays on the same plane; and this occurs, in trees and shrubs, by one series of the branches being always formed at the extremity of the stem every year; so that in time they appear at certain distances to surround the stem in successive series; as in the Silver Fir, Pinus *Picea* (fig. *a*, p. 245).

*b.* Two-ranked *(distichi)*, when the branches originating promiscuously are arranged in two opposite series*, as in the Elm, Ulmus *campestris.*

2. Alternate *(alterni)*, when they stand singly on each side of the stem, in such a manner, that between every two on one side, there is but one on the opposite side; as in purging Buckthorn, Rhamnus *catharticus*, or in the singular American plant, called Sweet Fern, Comptonia *asplenifolia*† (fig. *k*).


3. Scattered *(sparsi)*, when they are not given off from the stem in any determinate manner.

** *In direction.*

Branches are, relatively to the stem, either erect, or spreading.

1. Erect *(erecti)*, when they form a very acute angle with the upper part of the stem, and, consequently, nearly a right angle with the horizon. There are three varieties of erect branches.

* "Distichus ramos situ horizontali exserit." *Phil. Bot.* § 82. p. 24.

† *Veg. Mat. Med. of the United States*, vol. i. p. 224.

*a.* The approximated *(appressi)* (fig. *l*), when

*l.*

they rise in a direction nearly parallel to the stem; and are closely applied to it, as in Green Weed, Genista *tinctoria.*

*b.* Inflected *(introflexi)*, when the tips of the branches bend towards the stem; as in the Lombardy Poplar, Populus *dilatata.*

*c.* Fastigiate *(fastigiati)*, when the tops of the branches, from whatsoever part of the stem they spring, rise nearly to the same height; as in Sweet William, Dianthus *barbatus.*

2. Spreading *(patentes)*, when the angle, formed by the branch and the upper part of the stem, cannot be termed acute. Seven varieties of this direction of branching are described by authors.

*a.* Open, diffuse *(patuli, diffusi *)*, when the angle formed with the upper part of the branch is about forty-five degrees; as in great Hedge Bed-straw, Gallium *Mollugo.*

*b.* Very open, horizontal *(patentissimi)*, when the angle formed with the upper part of the stem is about 90 degrees; as in the Apple-tree,

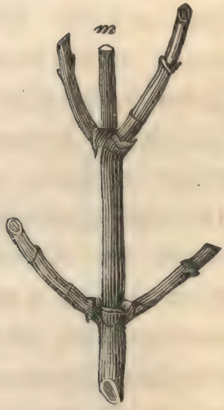
* "*Diffusus* ramis patentibus." *Phil. Bot.* § 82. 23.

Pyrus *Malus*; and the Asparagus, Asparagus *officinalis*.

*c.* Diverging *(divergentes)*, when they go off nearly at right angles with the stem, and appear as if verticillated, without being on the same plane; as the Stone Pine, Pinus *pinea*.

*d.* Brachiate, four-ranked *(brachiati *)* (fig. *m*), "when they spread in "four directions, crossing "each other alternately in "pairs; a very common "mode of growth in shrubs "that have opposite leaves, "as the common Lilac, Sy-"ringa *vulgaris* †."

m



*e.* Divaricated *(divaricati)*, when the direction is such that the angle formed with the part of the stem above the branch is rather more obtuse than that with the part below it; as in Fiddle Dock, Rumex *pulcher*.

*f.* Close *(conferti)*, when they are given off irregularly, and stand so thick, as to have apparently no spaces betwixt them.

* "*Brachiatus* ramos decussatim oppositos habet." *Phil. Bot.* § 82. 25.

† *Smith's Introd. to phys. and system. Bot.* 121.

*g*. Supported *(fulcrati*)*, when they project nearly horizontally, and give out root-like shoots from the under side; which extending until they reach the ground, take root, and serve as props to the branches; as in the Banyan tree, Ficus *religiosus*.

Such are the varied modes of branching; but many circumstances concur to alter and modify the natural directions of branches in trees. Thus, if a tree, which when it stands alone throws out many lateral, spreading branches, be planted in a thick grove, or forest, the lower branches will become weak from want of air and light, and fall off; and the tree, rising in height, will give out top branches only: while, on the contrary, a tree which is left when a wood is cut down, soon throws out lateral branches, and extends in the breadth of its shade, much more than it increases in stature. In the Cedar also, and some other trees of a pyramidal form, when, from age or accident, the top shoot, which is termed the runner, is taken away, the lower branches drop off and those of the summit of the tree stretch out broad and long; the whole aspect of the tree is changed, and from a beautiful and elegant pyramid, it becomes a spreading canopy, dark, awful, and im-

* "*Fulcratus*, ramis descendens ad radicem; *Ficus*." *Phil. Bot.* § 82. 27.

pressive. The finest examples of this alteration of form are the two venerable Cedars which grace the Apothecaries' garden at Chelsea. Even when the general character of the tree is not changed, circumstances occur to alter the natural direction of the branches: thus, if fruit-trees, which spread horizontally, be planted on a declivity, the branches still preserve a direction parallel to the surface of the earth, and consequently the angle which is formed between them and the upper part of the stem is much more acute than is natural on the side next the acclivity, and much more obtuse on the opposite. The steeper the declivity is, the more fertile the trees are said to become; which is undoubtedly owing to the position assumed by the branches, enabling the ground to operate in the same manner as a wall; but more beneficially. Cultivation, also, varies the natural aspect of plants: the buds, for instance, which on trees growing in a rich and cultivated soil, shoot into branches, often, from a deficiency of nourishment, run out into sharp-pointed thorns; and this is the case with almost every species of fruit-trees in a state of nature. The changing of these into branches by cultivation, is termed, by Linnæus, the taming of plants; but many plants, however, have appendages of this description under all circumstances of situation and culture.

*** *In strength, or the power they* (branches) *possess of supporting their own weight.*

In this respect branches are either sufficiently thick and strong to support the whole of their weight, whatever may be their relative size, situations, or directions; or they are so slender as to droop in a greater or less degree. When the latter state exists, the degree of drooping is denoted by specific terms. Thus they are said to be

*a.* Deflected, arched *(deflexi)*, when they hang down so as to describe a curve or arch, the convexity of which is towards the heavens; as in the Larch, Pinus *larix.*

*b.* Pendent *(reflexi)*, when the apex of the branch droops considerably below the line of its insertion; as in the Weeping Willow, Salix *Babylonica.*

*c.* Pendulous *(penduli)*, when they begin to droop nearly at the point of insertion, so as to hang almost parallel with the stem.

Such are the particulars connected with the external aspect of stems and branches, when remotely viewed, which are noticed by Botanists; but when these organs are examined a little more closely, we find many other important diversities, connected with surface and figure, that are necessary to be demonstrated; and without an accurate knowledge of which the student cannot

understand the descriptions of plants in the works of systematic writers.

With regard to surface, stems are either *bare* or *covered*. They are said to be,

1. Bare *(nudi)*, when the epidermis is perfectly free from appendages of every description, leaves, scales, spines, prickles, or any kind of pubescence. The superficies of naked stems varies considerably: it is termed,

*a.* Shining *(lucidus, nitidus)* when it glistens, as if varnished; as in shining Crane's-bill, Geranium *lucidum*.

*b.* Smooth *(glaber)*, when it is free from all kinds of roughness or hairiness*; as in Periwinkle, Vinca *major;* Petty Spurge, Euphorbia Peplus, &c.

*c.* Even *(lævis)*, when, throughout, it is perfectly free from inequalities; as in the Somniferous Poppy, Papaver *somniferum*.

*d.* Punctured *(punctatus)*, when it is covered with small yet visible perforations, either simple, or surrounded, at the orifice, with a raised border. In both instances, these punctures are probably the excretory ducts of subcuticular glands opening on the epidermis. Rue, Ruta *graveolens* (Plate 4, fig. 4); and perforated

* "*Glaber*, superficie lævi est." *Phil. Bot.* § 82. 18.

St. John's Wort, Hypericum *perforatum*; may be taken as examples.

*e.* Maculated, blotched *(maculosus, maculatus)*, when it is marked with spots or blotches; as in Hemlock, Conium *maculatum*, and great-flowered Anœthera, Anœthera *grandiflora* (Plate 4, fig. 5). The colour of stems is not generally noticed by Botanists, unless it be so remarkable and determinate as to constitute a good specific distinction, as in the instances just referred to; in which the maculated appearance of the stems is invariably present.

*e.* Leafless *(aphyllus*)*, when it is altogether devoid of leaves, as the Dudder, Cuscuta *Europea.*

*f.* Unarmed *(inermis)*, when devoid of prickles or spines.

*g.* Exstipulate *(exstipulatus)*, when without stipulæ; a species of appendage of which you must be supposed still ignorant, but which shall be described in the proper place. These negative terms are employed chiefly to distinguish those members of genera which contain species that display opposite qualities.

2. COVERED *(vestiti)*, when the epidermis is

* "*Nudus*, foliis destitutus; *Euphorbia, Cactus, Stapelia, Ephedra, Cuscuta.*" *Phil. Bot.* § 82. 2.

clothed with some kind of appendage; and according to the nature of this, the stem is designated by a term expressive of its covering. It is said to be,

*a.* Leafy *(foliosus, foliatus *)*, when it is furnished with leaves from the base to the apex (vide Plate 4, fig. 1, 2). When the stem passes through each leaf, it is denominated perfoliate *(perfoliatus)*, as in Yellow Wort, Chlora *perfoliata* (Plate 4, fig. 6).

*b.* Winged *(alatus)*, when the edges or angles are longitudinally expanded into leaf-like borders. (Plate 4, fig. 3.)

*c.* Sheathed *(vaginatus)* (fig. *o*), when it is embraced by the base of each leaf, as if by a sheath; as exemplified in the Grasses; Snake Weed, Polygonum *Bistorta*, &c.

*o*

*d.* Stipulated *(stipulatus)*, when it is furnished with stipulæ (organs which I shall have occasion afterwards to explain to you), at the axillæ of each leaf: as in the Common Vetch, Vicia *sativa*, broad-leaved Everlasting Pea, Lathyrus *latifolius* †; &c.

*e.* Tendril-bearing *(cirriferus)*, when it

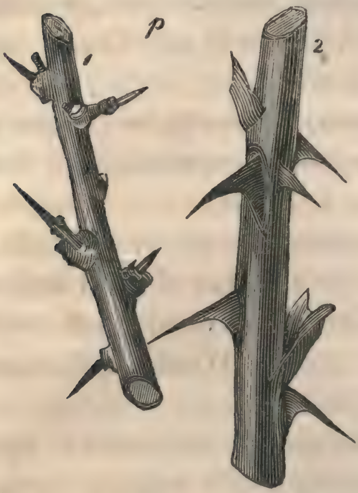
* "*Foliatus*, foliis instructus est." *Phil. Bot.* § 82. 3.

† Vide Plate 4, fig. 7, which represents the winged stem of Lathyrus *latifolius*; *a. a. a. a.* are stipulæ.

bears tendrils; as in the Passion Flower, *Passiflora* *; the Vine, Vitis, &c.

*f*. Bulb-bearing *(bulbiferus)*, when it is studded with bulbs in the axillæ of the leaves; as in several of the Lily tribe, *Lilium* †; Bulbiferous Coral Wort, Dentaria *bulbifera*, &c.

*g*. Spiny *(spinosus)* (fig. *p*, 1), when it is furnished with sharp spines, which are not productions of the bark, and, consequently, do not come off with it; as in Common Hawthorn, Mespilus *oxyacantha*, and the Sloe-tree, Prunus *spinosa*, &c.




*h*. Prickly *(aculeatus)* (fig. *p*, 2), when it is covered with sharp-pointed bodies, which separate with the epidermis; as in the Rose, Rosa *centifolia*, R. *Eleganteria*, &c.

*i*. Bristly *(setaceous)*, when its armature consists of brushes of minute bristles, divaricat-

* Plate 4, fig. 8. A small portion of a stem of a Passiflora; *a. a.* the tendrils; *b. b.* stipulæ; *c. c. c.* glands.

† Plate 4, fig. 9. A portion of the stem of Lilium *superbum*: *a. a.* the bulbs seated in the axillæ of the leaves.

ing from the points whence they are given off; as in creeping Cactus, Cactus *flagelliformis.* (Plate 4, fig. 10.)

*k.* Scaly *(squamosus)* (fig. *q*), when it is covered, more or less, with leafy scales, which are closely applied to its surface, as in Broom Rape, Orobanche *major.* When, however, the scales, instead of being succulent and leafy, are dry and membranaceous, this variety of the scaly stem is termed

q

* Ramentaceous *(ramentaceus)* (fig. *r*), as exemplified in slender branched Heath, Erica *ramentacea,* &c.

r

*l.* Pubescent *(pubescens),* when it is studded or covered with hair-like appendages. The pubescence varies very considerably, according to differences of soil, climate, and exposure; but, nevertheless, there are determinate characteristics which always, more or less, distinguish it, even in its variations. According to the appearance, the consistence and the quantity of pubescence, the stem on which it is found is named; thus it is termed

*α.* Hairy *(pilosus)* (Plate 5, fig. 1), when the pubescence consists of rather long separate

hairs; as in Mouse Ear, Myosurus *minimus;* Hawkweed, Hieracium *pilosilla;* Meadow Sage, Salvia *pratensis,* &c.

β. Hispid *(hispidus)* (Plate 5, fig. 2), when the hairs are stiff or bristly *, as in Borage, Borago *officinalis;* and Common Viper Bugloss, Echium *vulgare.*

γ. Downy *(tomentosus),* when the hairs are soft to the touch, like down, and so matted together, that the particular hairs cannot be distinguished; as in Shepherd's Club, Verbascum *thapsus;* and round-leaved Crane's Bill, Geranium *rotundifolium,* in which the pubescence is white; and Marsh Ledum, Ledum *palustre,* in which it is of a rust colour.

δ. Shaggy *(villosus)* (Plate 5, fig. 3), when the pubescence consists of long, soft hairs; as in Villose Speedwell, Veronica *villosa;* and downy Hedge Nettle, Stachys *germanica.*

ε. Woolly *(lanatus)* (Plate 5, fig. 4), when the fine hairs are long and matted; but easily distinguished from each other; as in woolly Hedge Nettle, Stachys *lanata,* and woolly Horehound, Ballota *lanata.*

ι. Silky *(sericeus)* (Plate 5, fig. 5), when the hairs are shining, and so arranged as to give the stem the appearance of being covered with silk.

Instead of pubescence, the covering is in some

* "*Hispidus,* setis rigidis adspersus." *Phil. Bot.* § 82. 21.

instances either a dry powdery, or a moist excretion. Of the former there are three varieties, and two of the latter. A stem is denominated

*a.* Hoary *(incanus, pruinosus)*, when the entire surface is strewed over with a fine white dust, which is easily rubbed off, like the bloom on Grapes; as exemplified on Dwarf shrubby Orache, Atriplex *portulacoides.*

*b.* Mealy *(farinosus)*, when the white powder is less minute, or is mealy; as in Bird's-eye Primrose, Primula *farinosa.*

*c.* Glaucous *(glaucus)*, when the dust or bloom is of a bluish green, or sea-green colour; as in the Palma Christi, (the castor oil plant,) Ricinus *officinalis*, &c.

*d.* Viscid *(viscidus)*, when it is covered with a clammy resinous exudation; as in clammy Catchfly, Silené *viscosa.*

*e.* Glutinous *(glutinosus)*, when the exudation is adhesive; but, instead of being resinous, it is gummy or soluble in water; as in clammy Primrose, Primula *glutinosa.*

Besides being covered with the appendages we have just examined, the surfaces of stems present inequalities from a variety of causes; and as these are fixed and always appear in every individual of a species, they are taken advantage of in the formation of specific distinctions; and, therefore, require to be pointed out. A stem is termed

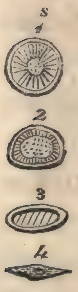
*a.* Scabrous *(scaber)*, when it is thickly covered with small papillæ, which are not visible, but can be felt on running the finger along it; as in Black Knapweed, Centaurea *nigra.*

*b.* Warty *(verrucosus)* (Plate 5, fig. 6), when it is studded over with small hard warts, or papillæ, which can be both seen and felt; as in Warty Spindle-tree, Euonymus *verrucosus.*

*c.* Vesicular *(papulosus)* (Plate 5, fig. 7), when the roughness depends on a small elevation of the epidermis containing a watery fluid, which gives the plant the appearance as if it were covered with ice; as in the Ice Plant, Mesembryanthemum *crystallinum.*

In point of FIGURE, stems are very diversified; and this is best ascertained in a transverse section. When a stem is thus examined, the following forms are found to exist.

*a.* Round, cylindrical *(teres, cylindricus*)*,



(fig. *s*, 1). A stem is said to be round when a transverse section appears nearly circular, for no stem is perfectly so: and the term cylindrical is employed with still more latitude, for all stems gradually diminish from the base to the apex. Stramonium, Datura *stramonium*, and Change-

* "*Teres* cylindricus." *Phil. Bot.* § 82. 12.

able *Hydrangea,* Hydrangea *hortensis,* may be taken as examples of the round; but the term is more or less applicable to all stems which approach to the circular form and have no angles.

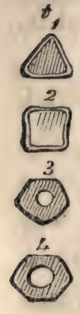
*b.* Half round *(semiteres),* (fig. *s,* 2), that is, round on one side and flattish on the other.

*c.* Compressed *(compressus),* (fig. *s,* 3), which implies that two sides of the stem are flat, and approach each other, or that the diameter of a transverse section of it is much greater one way than it is the other; as in flat-stalked Meadow Grass, Poa *compressa.* Besides the compressed stem, properly so called, there are two other forms of stems, which may be regarded as varieties of it: *α.* the two-edged *(anceps),* (fig. *s,* 4), when a compressed stem has the edges sharp, like a two-edged sword; as in striated Sisyrinchium, Sisyrinchium *striatum;* and *β.* the leaf-like membranaceous *(phylloideus membranaceus),* when the stem is so much flattened as to resemble a leaf; as in Spleenwort Cactus, Cactus *phyllanthus.*

*d.* Angled *(angulatus),* which means that a stem presents several acute angles in its circumference. There are three principal varieties of angled stems.

*α.* Obtuse *(obtusè angulatus),* when the angles are rounded and the sides flat. There are five sub-varieties of the obtusely angled

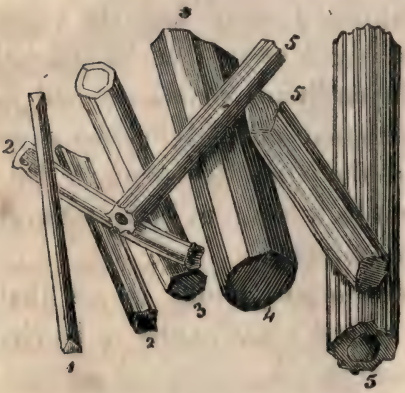
stems; in designating which, the word cornered is used, instead of obtusely angled, for the sake of brevity. A stem is said to be,




1. Three-cornered *(trigonus)*, (fig. *t*, 1, and *, 1), when there are three flat sides and three rounded angles.

2. Four-cornered *(tetragonus)*, (fig. *t*, 2), when there are four rounded angles. Sometimes the corners are bordered (fig. *, 2).

3. Five-cornered *(pentagonus)*, (fig. *t*, 3), when there are five obtuse angles. In this instance, also, the corners are sometimes bordered (fig. *, 5), and the intervals occasionally furrowed.

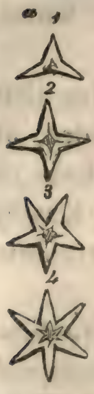



4. Six-cornered *(hexagonus)*, fig. *t*, 4), when there are six obtuse angles.

5. Many-cornered *(polygonus†)*, (fig. *, 4), when the angles are numerous and obtuse: β. Acute *(acutè angulatus)*, when the angles are sharp, and the sides hollowed.

† "*Digonus, trigonus, tetragonus, pentagonus, polygonus,* "præcedentis *(anceps)* species sunt." *Phil. Bot.* § 82. 13.

Of this variety of the angled stem there are, also, five sub-varieties:



1. Triangular *(triangularis)*, (fig. *u*, 1).
2. Four-angled *(quadrangularis)*, (fig. *u*, 2).
3. Five-angled *(quinquangularis)*, (fig. *u*, 3).
4. Six-angled *(sexangularis)*, (fig. *u*, 4).
5. Many-angled *(multangularis)* †. In many-angled stems the angles are not always so acute as in the other sub-varieties.

γ. Three-sided *(triqueter* ‡), (fig. *, 1), when there are three flat sides forming acute angles; as in Carex *acuta*.

e. Angular *(angulosus)*, implies that the angles are either very obscure, and the stem, consequently, can scarcely be placed in either of the foregoing arrangements; or that the angles are variable in number. There are two varieties of the angular stem, which have peculiar appellations; viz. α. Furrowed *(sulcatus)* (fig. *, 5), when the stem is longitudinally indented with deep and rather broad hollows, like those of a fluted column ‖; as in Common

† "*Triangularis, quadrangularis, quinquangularis, multangularis*, ex numero angulorum prominentium." *Phil. Bot.* § 82. 15.

‡ "*Triquetrus*, latera tria plana obtinet." *Ibid.* § 82. 14.

‖ "*Sulcatus* sulcis excavatis latis profundis exaratus." *Ibid.* § 82. 16.

Alexanders, Smyrnium *olustratum*: β. Striated *(striatus)*, when it is longitudinally indented with fine parallel lines *; as in Sorrel, Rumex *acetosa*.

*d.* Knotted *(nodosus)*, (fig. *w*, 1), implying that the stem is divided, at intervals, by swellings or knots; as in Knotty Cranes'-bill, Geranium *nodosum*, &c.


*e.* Articulated *(articulatus)*, that is, composed of joints, or apparently distinct pieces, united at their ends †. It is remarkable that Linnæus, in his definition of this form of stem, should have confounded it with the kneed stem, as he must have been well aware that many articulated stems are perfectly straight or erect. In some instances the articulated stems are knotted at the joints, but in others they are plain. Many of the Grasses afford instances of the former; while the Cactus tribe sufficiently exemplify the latter.

*f.* Kneed *(geniculatus)*, (fig. *w*, 2), when an ar-

* " *Striatus* lineis tenuissimis excavatis inscriptus." *Phil. Bot.* § 82. 17.

† " *Articulatus*, internodiis geniculatus: *Piper*." *Phil. Bot.* § 82. 31.

ticulated stem is more or less bent at each joint; as in Floating Fox-tail Grass, Alopecurus *geniculatus;* Three-flower Fescue Grass, Festuca *triflora*, &c.

Such are the diversities which stems externally present to the eye. But these, although in their natural state they are sufficiently fixed to enable systematic Botanists to employ them as distinctive characteristics of species, which could not otherwise be distinguished *; yet, are apt to vary, owing to peculiar circumstances connected with situation, climate, and soil. Thus we find a stem which, in its natural state, is round, assume a flattened appearance as if two or more stems or branches were united longitudinally side by side: an anomaly which is not uncommon in the Ash, several species of Daphne, the greater Nasturtium, Tropæolum *majus*, and many other herbaceous plants; and is denominated by authors † the clustered stem, *caulis fasciculatus*. It is not easy to account for this effect, since it is evidently not the simple lateral union of one or more stems or branches, a circumstance which might be produced by pressure abrading the epidermis and cellular layer of the bark, and bringing the liber or

* "Caulis in multis plantis ita essentiales præbet differentias, "ut eo demto, nulla certitude speciei." *Phil. Bot.* § 276.

† *Smith's Introduction*, p. 127. *Keith's System of physiological Botany*, vol. ii. p. 277.

innermost layer of each of the united stems into contact; for, were this the case, the pith of each of these conjoined stems would be still entire, and the aggregate would appear as distinct cylinders, according to the number of the stems; whereas in the fasciculated stem there is one flat pith only, and the other parts of the stem are, in arrangement and number, the same as if the anomaly did not exist. The idea, therefore, of the fasciculated stem arising from the pressure of one or more contiguous stems, and a natural graft being thus formed, as has been suggested by Mr. Keith, cannot be admitted. Several other anomalies occur in the configuration of stems; but as these are generally either the consequence of disease, or of some obstacle to the natural development in the individual plant occasioned by insects, the consideration of them may be deferred until we come to treat of the diseases incidental to the vegetable system.

Independent of the diversities which we have already examined, STEMS have been properly distributed into distinct *species*. In this classification, Linnæus and others who have copied after him, enumerate six species of stems; but among these the footstalk of the leaf and the frond are improperly included; for, as the former is decidedly a part of the leaf, and separates with it when it falls; and the latter is a peculiarity connected with the foliage of distinct tribes of plants, the Palms, the

Algæ, and the Ferns; and is itself supported on a species of real stem (which I shall soon have occasion to describe to you), the stipe*, neither of them can with propriety be classed with stems. Mirbel† and Mr. Keith‡ omit the flower-stalk in their enumeration of the species of the stem, and certainly with some propriety; for, although it closely resembles the stem in its structure, yet, in an elementary work, it is undoubtedly more intelligible to the student to describe it as a part only of it bearing the fructification, except when it proceeds immediately from the root. Contemplating the subject nearly in a similar point of view, I think we are authorized in distributing stems into *five* distinct species:—the *trunk*, the *stalk*, the *straw*, the *scape*, and the *stipe*.

1. TRUNK *(Truncus)* is the appellation given to the stems of trees and shrubs §. The trunk is

* "*Frons* est dilatatio vegetabilis herbacea quæ arcte "cum cormi specie, qua sustentatur cohæret, Palmis, Filici-"bus, Algisque propria." *Willdenow, Spec. Plant. tomus* v. *Introd.* p. xxi.

† *Elémens de Phys. vég.* p. 99 and 622.

‡ *System of physiological Botany*, vol. i. p. 43.

§ Linnæus uses the term trunk in the generic sense in which I have used the word *stem*; and thus defines it:—" TRUNCUS "folia et fructificationem profert; species ejus sunt vii. *Caulis*, "*Culmus*, *Scapus*, *Pedunculus*, *Petiolus*, *Frons*, *Stipes*; at "*Ramus* pars est." *Phil. Bot.* § 82.

characterized by its ligneous structure, by being always perennial; generally naked at the lower part; and divided and subdivided towards the summit into branches and twigs, bearing leaves and the fructification. It is thickest at the base, and gradually diminishes to the apex; is covered with a thick, often dry and cracked bark; and internally is composed of a central pith, surrounded by ligneous layers, the number of which varies according to the age of the plant. When it rises to a moderate height, like a simple column, before it divides into, or gives off branches, it is said to be *arboreous,* as exemplified in the Oak, the Elm, and the majority of trees; but when the divisions or branches occur near to the soil, it is termed shrubby, *fruticosus;* as in the Lilac, the Rosemary, and such-like. These terms, however, are always to be understood as having a relative signification only; for various circumstances, such as change of soil, climate, and the efforts of art, may metamorphose shrubs into trees, or reduce these again into shrubs; transitions which are by no means uncommon.

2. STALK *(Caulis)* is properly applicable to the stems of herbaceous plants only; although the term is frequently used in a sense synonimous with *trunk.* The specific characteristics of the stalk are, that it is rarely ligneous, and lives but

one or two years in the natural state of the plant. It may be divided and subdivided into branches, like the trunk; and a greater number of these diversities which have been described belong to the stalk rather than to the trunk.

3. Straw *(Culmus)* is a name strictly confined to the stems of the Grasses, Rushes, and the gramineous cerealiæ *. It is either hollow, or partially filled with pith, and generally knotted, articulated, and kneed; but very rarely branched. The knots are solid, confined to the articulations, and give origin to the leaves, which are sheathing at their base. It increases in length, tapering gradually to the apex, but not in diameter, is round, compressed, or triangular; and is frequently hairy; but, as Sir J. E. Smith properly observes, there is "no instance of such a scaly "culm as Linnæus has figured in his *Philosophia* "*Botanica*, t. iv. f. 3 †."

4. Scape *(Scapus)*, strictly speaking, is a flower-stalk, as it bears the parts of fructification only, and is entirely devoid of leaves; but, nevertheless, as it proceeds immediately from the root, it may be properly classed as a stem ‡. It is al-

* "*Culmus* truncus proprius *Gramini*, elevat folia fructi-"ficationemque." *Phil. Bot.* § 82. B.

† *Smith's Introduction*, p. 128.

‡ "*Scapus* truncus universalis elevans fructificationem nec "folia: *Narcissus, Pyrola, Convallaria, Hyacinthus.*" *Phil. Bot.* § 82. C.

ways herbaceous; and is found either simple, and bearing one flower only, as in common Dandelion, Leontodon *taraxacum;* or divided, and many-flowered, as in Cowslip, Primula *veris*.

5. Stipe *(Stipes)* is the term used to express the stem of Palms, Ferns, Fuci, and Fungi. It is generally cylindrical; but sometimes swollen in the middle, and bears a frond, or the foliage which is peculiar to it, at its summit. In the *Palms* the stipe is in general a simple column bearing a spreading plume of leaves; and of the same diameter at the summit as at the base, except in a very few genera *, which throw out branches. It is marked at regular distances by the cicatrices of the fallen leaves; and increases in height by additions made to its summit by the development of a central gem, which throws out annually a new circle of leaves. In the *Ferns* it varies considerably in form, being round, channelled, triangular, and quadrangular; and is either devoid of vestiture, or is chaffy, scaly, spiny, or muricated, that is, covered with sharp hard tubercles: and the same diversities occur in the stipes of the *Fuci*. In the *Fungi* it is generally fleshy or leathery; but it varies both in substance and form; and although, in the greater number of instances, it is affixed to the centre of the cap,

* *Dracæna*, &c.

or *pileus*, as in the Mushroom, or nearly so; yet in others its attachment is to the side of that body.

Such are the peculiarities, connected with the exterior of stems, necessary to be noticed in this stage of our inquiries: in closing our examination of them, this question spontaneously presents itself: why is there so great a diversity of form, vestiture, and mode of branching in the vegetable organs? No satisfactory reply can be advanced; and, therefore, we are left to imagine that, as nature appears to delight in variety, the diversified and graceful forms and appearances of plants may be one source of pleasure prepared by Divine Benevolence for mortals. Be this as it may, man has not failed to render them accessaries to his comfort, and subservient to his necessities. In the cool shade of the branching arms of the Beech, or under the pillared canopy of the Banyan, he shuns the ardour of the meridian blaze; with the shrubby and spiny Hawthorn, or the prickly Cactus, he encloses his fields; while the pliant Osier is woven into baskets to transport their produce to the crowded city: the tall and straight Pine rises a mast, on which he spreads the sail that enables him to transport the riches of distant climes to his native shores; and the incurved ribs of the venerable Oak, launched into the main, float, the protectors of his maritime rights, and the bulwarks of his national independence.

## LECTURE VII.

SUBSTANCE AND ORGANIZATION OF THE STEM AND BRANCHES: — ANATOMICAL DEMONSTRATION OF THE COMPONENT PARTS OF THESE ORGANS—THEIR FORMATION, INCREASE, AND REPRODUCTION.

THE examination of the external aspects of stems and branches, which we have just concluded, will readily enable you to form an estimate of the importance of the correct knowledge of terminology to the systematic Botanist; for, without a definition and name for each diversity of feature, which the vegetable organs present to the sight or the touch, it would be impossible for him to fix these specific distinctions, by which alone the different members of the same family of plants can be readily recognised. This diversity, as you have seen, is very considerable in the external character of the stem and branches; but when we extend our examination to their interior structure, or organization, we find it confined within very narrow limits: nor will this excite our astonishment when we reflect, that nearly the same end is to be accomplished by these organs, whatever may be the habits or the physiognomy of the plant.

It is now my object to direct your attention to these differences, and to point out to you the circumstances in which they consist.

If we take a number of stems and branches of different kinds of plants, and cut, or break, or tear them transversely and longitudinally; we shall find that some of them are easily divided, whilst others resist almost all our efforts; that some are moist, succulent, and fleshy; others fibrous, spongy, and dry; and others again formed of both succulent and dry parts; the latter possessing very different degrees of compactness, induration, and tenacity. But, however considerable these differences may appear, the more we investigate the subject the more we shall be convinced, that, as far as respects *substance*, the stems and branches of the whole of the vegetable kingdom may be arranged under two classes,—the *Woody* and the *Herbaceous*.

A. Woody stems *(Caules lignosi)* are those which contain a very large proportion of ligneous fibre; or in which wood forms comparatively the greater part of their bulk. It is found either in threads or bundles which run longitudinally from the base to the summit of the stem; or is united in one mass, formed of concentric circles, which cohere and compress each other nearly from the centre to the surface of the stem:—the tribe of

Palms affords examples of the first description of ligneous stems, and all other trees of the second. As far as respects substance, however, ligneous stems are not arranged according to the diversity of structure I have just hinted at; but according to the degree of cohesion which binds together their ligneous fibres. Botanists have, therefore, divided woody stems into two genera, the *solid* and the *fibrous*.

1. The *solid* woody stem (C. *solidus)* is that in which the cohesion is uniform, and the wood, consequently, compact and indurated; sometimes to a degree on which the knife will make scarcely any impression.

2. The *fibrous* (C. *fibrosus)* is that in which, the cohesion being irregular, the wood is constituted of fibrous bundles; which, although adhering to each other, can be easily separated, either by tearing or by maceration.

Ligneous stems of every description are perennial.

B. Herbaceous stems *(Caules herbacei)* are those which contain a small proportion of woody matter; but are composed chiefly of cellular substance, and consequently can be easily cut or divided. There are three distinct kinds of herbaceous stems: the *fleshy*, the *spongy*, and the *hollow*.

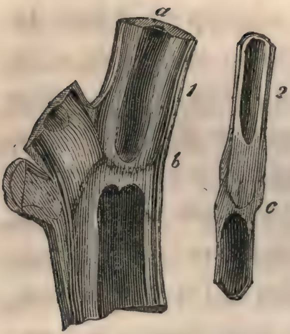
1. The *fleshy* stem (C. *carnosus)* is that in which the cellular substance, of which it is composed, is turgid with fluids; and when cut, presents a smooth, uniform moist surface, similar to that of a young Cucumber when transversely sliced. The common House-leek, Sempervivum *tectorum*; and most of the sea-weeds, Algæ, afford examples of the fleshy stem.

2. The *spongy* stem (C. *spongiosus)* is composed of a compressible, elastic, cellular substance, contained within an epidermis; either dry, the cells being filled with air only; or moist, the cells being partially filled with fluid, as in a sponge. The Mushroom tribe, *Fungi*; Indian Corn, Zea *mays*; and Great Cat's-tail, Typha *latifolia*, have spongy stems.

3. The *hollow* stem (C. *fistulosus)* is a succulent or fleshy hollow cylinder, surrounded by a circle of vessels and ligneous threads, immediately under the epidermis; and generally lined with a dry white spongy layer of pith. There are two varieties of the hollow stem.

*a.* The *uninterrupted (sine septis transversis)*; when the hollow, or cavity, extends from the base to the apex of the stem, as in the genus Coreopsis *(Coreopsis)*.

*b.* The *interrupted (septis transversis intertinctus)*; when either the longitudinal cavity is divided, at regular distances, by parti-




tions or diaphragms (fig. *a*, 1); or the stem is knotted, and apparently made up of separate hollow portions, shut at each extremity, and united at the knots. The different species of Horse-tail, Equisetum; Manured Reed, Arundo *donax;* Common Water Dropwort, Œnathe *fistulosa;* the Castor oil plant, Ricinus *officinalis;* and almost all the Grasses, and the Cerealia, afford examples of this variety (fig. *a*, 2).

Such is the diversity of substance of stems and branches; we have now to examine the anatomical construction of these organs. To the student, this inquiry is not only important, as displaying the structure of the stem itself, and thereby enabling him to comprehend more perfectly its functions and mode of growth; but, as all the parts concerned in the vegetable functions, as far as the preservation of the individual is concerned, are seen in the stem; by a correct knowledge of its organization he becomes acquainted with that also of the root, the leaves, and even, in some respects, of the flowers and the fruit. In this investigation it is essential to adopt some arrangement; and although none, which has yet been attempted, is free from just causes of cri-

ticism, and probably none can be devised altogether unobjectionable; yet, if by any the examination can be facilitated, the attempt to form one, as nearly perfect as the nature of the subject will admit of, is at least praiseworthy.

The only arrangements which I shall notice, are those of Desfontaines and Mr. Keith. Desfontaines' method is founded on the fact, that there are two grand divisions of plants, the Monocotyledonous * and Dicotyledonous †; each of which displays a distinct and specific mode in the distribution of the parts of the stem. In the individuals belonging to the first, the stem consists of bundles of woody fibres and vessels, interspersed throughout a cellular substance, and decreasing in solidity from the circumference to the centre; in those of the second it is composed of concentric and divergent woody layers, decreasing in solidity in the opposite ratio, or from the centre to the circumference, and containing a pith in a central canal ‡. But, as Mr. Keith has justly observed, this arrangement does not exhaust the subject: as, independent of the Polycotyledonous plants which may be classed with the Dicotyledonous, there is no account taken of

* Plants, the seeds of which have one lobe only.

† Plants, the seeds of which have two lobes.

‡ Vide *Mém. de l'Instit. Nat.* tome i.

those tribes which are altogether destitute of seed-lobes; the stems of which, in their organization, exhibit neither the woody bundles of the one, nor the layers of the other. Mr. Keith, in order to obviate this objection, has arranged stems, in reference to their internal structure, into three classes:—1. *The caudex an homogeneous mass;* 2. *The caudex an heterogeneous mass;* and, 3. *The mass consisting of bark, wood, and pith**. This arrangement is undoubtedly less exceptionable and more comprehensive than that of Desfontaines; but Mr. Keith has erred in arranging, in his second division, the herbaceous stems of dicotyledonous and polycotyledonous plants; for, although these have no concentrical circles of formed wood, such as characterize the ligneous stems of those tribes, yet the distribution of the ligneous matter and of the pith coincides sufficiently with that of these parts in the real woody stems to allow them to be classed together; whilst it has little or no affinity with that of the ligneous bundles in the monocotyledonous stems with which they are classed in Mr. Keith's arrangement. A more perfect classification, perhaps, may be formed, by adopting the first division of Mr. Keith's arrangement and adding to it those of Desfontaines; as, besides embracing the whole of the subject, it leads us first to the examination of

* *System of physiological Botany,* vol. i. p. 287 & seq.

those stems which are the simplest, because composed of the fewest parts; and progressively prepares us to understand the organization of those of a more compound nature. I shall, therefore, attempt such an arrangement, and class stems, in reference to their anatomical structure, into the three following divisions:

i. *Stems which display, internally, an apparently homogeneous mass.*

ii. *Stems which proceed from monocotyledonous seeds.*

iii. *Stems which proceed from dicotyledonous and polycotyledonous seeds.*

i. Stems which display, internally, an apparently *homogeneous mass*, when examined by the unassisted eye, seem to consist simply of an epidermis enclosing a parenchyma, composed either of cellular substance, of very different degrees of succulency, sponginess, dryness, and density; or of interwoven fibres, forming a leathery, or a felt-like texture, or one not a little resembling that of washed animal muscle which has been macerated in spirits. When examined, however, by the aid of a good microscope, these different appearances of the internal mass are all found to consist of cellular substance, with vessels running through it, and anastomosing in a variety of directions. Mirbel erroneously asserts that this description of

stems is destitute of vessels *; for their presence, at least in the stipes of the Mushroom tribe *(Fungi)*, and the stalks of many of the Algæ, is demonstrable by placing a small transverse slice of any of them under a powerful microscope. They are not, indeed, so readily distinguished in a longitudinal slice, a circumstance which I am inclined to ascribe to the transparency of their coats confounding them with the cellular substance in which they are imbedded; and which consists of continuous, oblong cells, the membrane forming the sides of which is of very different degrees of thickness; but, nevertheless, they may be made out by any one accustomed to the use of the microscope. I have never been able to satisfy myself of what description these vessels are, although it is evident, as Mirbel remarks, that they are neither the spiral, nor the annular; but I suspect them to be the moniliform. The epidermis, which cannot be separated from the cellular mass it covers, is pierced with imperceptible pores, but, according to Mirbel, it has no miliary glands. In the different tribes of plants which afford examples of this description of stems, the reproductive organs are either altogether deficient, or so obscure as to have eluded the researches of phyto-

* Vide *Elémens de Phys. végét.* 1ere Partie, p. 37; and *Journ. de Botanique*, tom. iii. p. 36.

logists; and thence they have been regarded as agamic. Many of them have no stem; but among those which possess it, in some it is solid, or rather entire, in others hollow; and in the latter case, the cavity is often partially lined with a very lax, dry, cellular web *. A conspicuous root is rare; and, when it exists, consists of a few small radical fibres only, composed of a single thread, covered with a cribriform epidermis. Scarcely any facts are yet known respecting the development and growth of this description of stem.

ii. Stems which *proceed from monocotyledonous seeds* are more complex in their structure than the preceding. They are composed of two distinct parts, ligneous and cellular, which assuming a determinate character, enable these stems to be readily distinguished, even by the naked eye. They comprehend both solid and tubular, or entire and hollow stems; and as there is some difference in the arrangement of the parts in these varieties, we shall examine them separately.

* See Plate 5, fig. 1, which represents a longitudinal section of the stem of Tall Agaric, Agaricus *procerus; a.* the stem; *b.* its lax cellular lining, or pith, which in this example nearly divides the hollow of the stem into two unequal cavities; *c.* a fragment of the hat or *pileus,* to show the simplicity of its union with the stem.

*a.* If a *solid* monocotyledonous stem, that of a Palm for example, be cut, either longitudinally or transversely, it is seen to consist of an epidermis enclosing ligneous bundles or cords, more or less symmetrically distributed in a parenchyma or medullary substance. If the section be longitudinal, these ligneous cords are observed to run longitudinally, and extend from the base to the apex of the stem, sometimes in straight lines; but occasionally assuming a zigzag direction, so as to touch each other at different distances: closer together and firmer towards the circumference of the stem, and more apart and softer as they approach its centre *. If the section be transverse, the divided extremities of the ligne-

* Vide Plate 5, fig. 2, 3, 4. Fig. 2 represents the section of a transverse cutting of a Palm, the Ptychosperma *gracilis* (copied from a plate of Mirbel); *a.* the ligneous bundles closer together, more indurated, and in greater numbers than in the space marked *b*, in which also, however, they are less distant and more compact in that portion which is farther from the apex of the section, than in that which is nearer to the centre of the stem.

Fig. 3. A. a transverse slice of the scape of the Tiger-flower, Tigridia *pavonia*, slightly magnified; the ends of the ligneous bundles being shown by the white dots, which in the natural stem appear on a green ground.

Fig. 4. A longitudinal section of the scape of Great Reed-mace, Typha *latifolia*, showing the ligneous bundles, which in this instance do not inosculate.

ous bundles appear like spots, which are in some instances of a dark colour, and in others white, dispersed over a white or a green ground, in the order just described. The epidermis adheres closely to the parenchyma beneath it; and in some plants of this class, the greater density of the cellular substance at the circumference gives the appearance of a bark, which is never, however, present in this description of stem. Such is the general character, and the distribution of the parts, in what may be termed the *ligneous* solid monocotyledonous stems*; but when they have more of an herbaceous character, such, for example, as the scape of Great yellow Garlick, Allium *Moly*, there are no indurated ligneous cords; but the vessels run in the midst of longitudinal layers of condensed cellular matter, and in a transverse section appear as white dots forming a circle round the central cells, which are generally much larger than those of the circumference, and assume in some degree the aspect of a pith †; so that in the longitudinal section, the

* The student, who cannot procure the stem of a Palm, may attain an excellent idea of the internal structure of the solid monocotyledonous stem in the flower-stalk of the Tigridia *pavonia*, which is now very common in the stoves of the London florists and nurserymen; or in that of the Typha *latifolia*, not unfrequent in ditches, flowering in July.

† Vide Plate 5, fig. 5. A. a transverse slice of the scape of Allium *Moly*, nearly of the natural size.

diameter of the stem appears divided by two seemingly solid cords, into three nearly equal compartments. Mirbel, in treating of this description of stems, says, "their pith, instead of being en-"closed in a canal, in the centre of the stem, ex-"tends almost to the circumference *;" but there are exceptions to this remark, as, for instance, in the Rush, Juncus, which has a perfect pith, surrounded, however, by a cellular tube, in the substance of which the vascular cords characteristic of the monocotyledonous stems are perfectly apparent, arranged in beautiful order; and distinguish it from an herbaceous dicotyledonous stem, the vessels of which, as I shall afterwards demonstrate to you, are arranged in a very different manner.

Such are the appearances which, to the naked eye, or to the eye aided by a common lens, the solid monocotyledonous stems present. Under the microscope, we perceive that each ligneous cord is composed of very narrow oblong cells, and of vessels which are either spiral, or annular, or porous, those in the centre being always spiral; that, in the cellular substance of the more solid stems, the cells are chiefly oblong, whilst in that

* "Et leur moelle, au lieu d'être resserée dans un canal, "au centre de la tige, s'étend presque jusqu'à la circonférence." *Elémens de Phys. vég.* Partie 1. p. 117.

of the herbaceous they form irregular hexagons, except towards the circumference, and in the immediate vicinity of the vascular cords *; and that the membrane forming them is perforated with minute pores, surrounded by a glandular border. In the common Rush, Juncus *conglomeratus*, and some other monocotyledons, the cells of the pith are of a very curious structure: appearing, in a transverse section, like minute heptagonal wheels or circles divided by rays passing from the centre; and these are evidently filled with air †. In common Mare's-tail, Hip-

* Vide Plate 5. Fig. 3, B. represents a magnified section of fig. 3, A. to demonstrate the greater density of the cellular substance towards the circumference.

Fig. 5, B. a highly magnified section of fig. 5, A. *a.* the cellular substance more condensed close to the epidermis than in the heart of the stem; *b.* the vascular bundles. Fig. 5, C. a highly magnified longitudinal section of the semi-diameter of the slice A. which has the appearance of fig. 5, *d.* to the naked eye: *a.* the cellular matter, close to the epidermis, appearing as oblong cells; *b.* one of the seemingly solid cords, which form the circle of vascular bundles, consisting of two spiral vessels, surrounded by oblong cells; *c.* the cellular substance which constitutes the mass of the stem. In this view the membrane forming the walls of the cells is seen studded with points, which, under the microscope, appear to be either amylaceous granules or circular apertures surrounded by a border. Mirbel supposes they are pores, and that the border is glandular.

† Vide Plate 5, fig. 6, which represents a magnified section of a transverse slice of the common Rush: *a.* the pith com-

puris *vulgaris,* the air-cells, which are on the outside of a central column, composed of vascular and ligneous bundles, are divided from each other by smaller cells, which are filled with aqueous fluid: whilst, at every whorl of leaves, bundles of vessels are given off from the central column, and these are surrounded by condensed cellular matter, which forms a kind of diaphragm; by the repetition of which the whole stem is divided into compartments at regular intervals *.

posed of circular or heptagonal cells, divided by septa passing from the centre of each, like rays; *b.* the cylinder which surrounds the pith; composed of green parenchymatous matter, in which bundles of spiral vessels (*c. d.*) run, surrounded by condensed cellular matter; *e.* departments consisting of air-cells dividing the vascular bundles; *f.* bundles, apparently of entire vessels, forming the striæ on the surface of the stem; *g.* lacunæ or open spaces between the pith and its enclosing tube. If I might be permitted to hazard an opinion regarding the use of this organization, it would be this: that, as the Rush has no leaves, the green parenchymatous tube is intended to perform a function analogous to that of leaves, these organs consisting chiefly of a similar substance.

* Plate 5, fig. 7, a section of a transverse slice of the stem of common Mare's-tail, Hippuris *vulgaris*, an aquatic plant: *a.* the exterior, or cellular part (enclosed merely by the epidermis), consisting of large air-cells, each surrounded by smaller cells, which are generally found turgid with aqueous fluid; *b.* the central column, which consists chiefly of spiral vessels, one of which is drawn out at *c.* All aquatic plants contain very large air-cells; which are most abundant in their stems, if their leaves be few or comparatively small, or the greater number of them is above the surface of the water; and

It is necessary to notice, particularly, the structure of one variety of the solid, herbaceous, monocotyledonous stems; as it constitutes the link betwixt the solid and the fistular monocotyledons. It is articulated, giving off leaves at the joints only; and these are sheathing or embrace the stem. On dissection, we find the vascular bundles, which can scarcely be called ligneous, enclosed in a cellular parenchyma, and running in straight lines between the joints; but at these they inosculate in arches, and send off horizontal branches, some of which terminate in the leaves and others in the lateral shoots that originate at their basis. This structure is beautifully displayed in the stem of Spiderwort, Tradescantia *Virginica,* in which the circles forming the annular vessels being nearly opaque, the course of the vascular bundles is readily traced; and the manner in which the vessels are given off, and inosculate, distinctly seen by the aid of the microscope *.

in the leaves, if these be large or mostly immersed, as for instance the Common Reed-mace.

* Vide fig. 9 and 10, Plate 5. Fig. 9, *a. a. a. a. a. a.* the vascular cords, as seen by means of a good lens by reflected light, forming arches at the joint; *b. b.* the base of the leaf, with the vessels which supply it proceeding nearly from the centre of the joint; *d.* the fragment of a lateral shoot, the vascular bundles connected with which are seen originating from the same spot as those of the leaf. Fig. 10, a small portion of the joint highly magnified, to display the structure of

*b.* The *hollow* or fistular monocotyledonous stems are composed of distinct portions, united by knots; at each of which the cavity is divided by a diaphragm: or, rather, each portion may be regarded as a distinct individual, which takes its origin from one knot, and terminates in another, out of which again a new individual arises, and so on in succession, as I shall more particularly describe in explaining the mode of growth of these stems. The general structure of this description of stems is best exemplified in the Grasses. Thus, in Wheat we perceive the upper articulation rising within the knot, in which the lower has terminated; with the leaf which infolds it crowning the embracing knot *. The organization of this variety of the monocotyledonous stem cannot be readily distinguished without the aid of the microscope. It is seen, in a longitudinal section, to consist of several layers of narrow oblong cells, which constitute its exterior and more solid part; and of an interior more open cellular substance,

the vascular cords and the inosculation of the vessels. *a.* The bed or sheath in which the vessels run; *b.* the vessels themselves apparently composed of separate rings, held together by small spicular bodies, which appear as lines on the surface of the vessels, within the transparent sheaths; when detached, they appear like acicular crystals. The cells are studded with amylaceous granules.

* Vide Plate 5, fig. 11. *a.* the knot of the straw bearing a fragment of its leaf; *b.* the new articulation rising within the knot.

enclosing vascular, ligneous cords, composed of oblong cells like those on the circumference, surrounding spiral and annular vessels. In the transverse section the divided extremities of these cords appear as clustered vascular spots in the cellular substance *.

The bark, if the surface of the stem can be so named, of the more solid monocotyledons is formed of the footstalks of the leaves; but the real epidermis of both the ligneous and herbaceous stems of this tribe, is always, as has been already stated, so closely applied to the part which it covers, as to be inseparable from it by any means. Owing to this circumstance it appears of a cellular structure, and its character is regulated by the nature of the parts it immediately encloses. In those plants, in which it can be readily examined, it displays, under the microscope, a regular series of organic exhaling pores, each apparently surrounded by a glandu-

* Vide Plate 5, fig. 8. A. B. C. A. represents the transverse slice of a stem of Wheat, as seen through a good lens; B. a longitudinal section of the slice highly magnified; *a.* the outer cellular substance, composed of oblong cells and entire vessels; *b.* the interior cellular lining of the cylinder of the stem; *c.* a vascular bundle, consisting of a spiral vessel surrounded by oblong cells; C. a transverse section of the slice; *a.* the tubular cells immediately under the epidermis; *b.* the common cellular substance; *c.* the vascular bundles.

lar border; as is beautifully demonstrated in the culm of Wheat*: but in some plants, as, for instance, the Common Rush, these apertures are perceptible in the furrows only between the striæ, the elevations being apparently free from any exhaling pores†. In some of the herbaceous dicotyledons, silex is found deposited in, or rather immediately under, the epidermis.

Monocotyledonous stems, those even of the largest diameter, display no medullary rays, such, as I shall soon have occasion to demonstrate, as characterize the dicotyledonous; nor do such appear to be necessary, owing to the extensive distribution of the cellular matter throughout the substance of these stems. The woody bundles, however, become indurated by age, and the more external being enlarged by the deposition of new ligneous matter, they at length occasionally touch each other, and form a circle of continuous wood; but the interior bundles never attain this state, and are always sufficient to distinguish the stem as a monocotyledon.

Monocotyledonous stems increase in length or height; but, with very few exceptions, not in diameter. As I have had no opportunity of tracing the manner in which this is effected, in the ligneous

* Vide Plate 5, fig. 12.

† Vide Plate 5, fig. 13. *a.* the appearance of the cuticle over the ridges; *b.* its cribriform appearance in the furrows.

monocotyledons, I shall follow the description of Mirbel, in explaining to you the growth of a Palm. When the young plant, rising from the seed, appears at the surface of the ground, the leaves, originally folded up and sheathed within each other, separate themselves, increase in number, and form a sheaf-like group. Those on the circumference now spread out, perform their functions, and are detached; but their bases remaining, form a solid or ligneous ring, which is the origin of the stem. Within this circle the sheaf of leaves rises vertically; owing, perhaps, to the resistance at the circumference; and the exterior ones having spread out on every side in the same manner as the former, drop after a time, also, and leave their bases to form another circle; within which the sheaf still rising, again spreads out another range of leaves; and in this way the stem is gradually formed by the evolution of the terminal leaf-bud, and the induration of the footstalks of the fallen leaves. The whole stem displays the cicatrices of the successive circles of detached leaves, and these becoming hardened by their exposure to the air, and the ligneous bundles within them being older, in a direct ratio as they are nearer to the surface (the development of parts always taking place in the centre), the substance of the stem is necessarily softer within, and harder as it approaches the circumference.

Owing to the mode of growth, also, which has just been described, the stem is always naked, columnar, and terminated with leaves and fructification in the form of a magnificent crown, as exemplified in the Palms. The *stipe*, therefore, or this kind of monocotyledonous stem, may be regarded as a fasces of ligneous vascular rods imbedded in cellular substance, and terminating in leaves *: and its vitality being, in a great degree, dependent on the herbaceous part, if the central bud, or cabbage †, as it is commonly called, be cut off, the whole plant immediately dies. In tropical climates, some kinds of Ferns rise with a stipe resembling that of the Palms; but this appears to be, according to Mirbel, "a

* The height to which some Palms arise, without increasing in diameter, is truly astonishing. Thus the Ptychosperma *gracilis* rises more than sixty feet above the surface of the ground, with a stem not four inches in thickness. The elevation of the Areca *oleracea* is often not less than one hundred and eighty feet; and "although," says Mirbel, "its diameter "is greater than that of the Ptychosperma, yet, it is certain "that it never increases in thickness." *Elém. de Phys. vég.* t. i. p. 12. Its stem is, nevertheless, thicker in the middle than either at the base or the summit, when the Palm has attained to a certain age; which is justly ascribed to its vegetative powers being more vigorous at the middle period of its existence.

† The terminal bud of the Areca *oleracea* is boiled and eaten as a delicacy, under the name of Cabbage; and the plant is called the Cabbage Palm.

"simple fasces of petioles, or leaf-stalks *;" although circumstances occasion these to unite in the interior of the stipe, and form masses of compact wood. This variety of stipe does not increase in diameter.

The Aloes, the Yucas, and the Dracæna differ in their mode of growth from the Palms, inasmuch as they give off branches and increase in the diameter of their stems. From the observations of M. Aubert du Petit-Thouars †, who traced the mode of branching, and the consequent increase of diameter in the stem of the Dracæna, it appears that the branch originates in a small protuberance under the epidermis, which it soon ruptures; and extending, first unfolds some scales and then leaves, the result of the successive development of which is a cylindrical branch composed of ligneous cords, similar, in every respect, to the parent stem, and seated upon it like a graft. The ligneous cords, at the point of their junction with the adult stem, spread out at first like rays, and then extend, in an opposite direction to the growth of the branch; the exterior descending in straight lines towards the earth, whilst the others, after ascending a little at first, soon, also, bend down and take the same course, which the whole

* *Elémens de Phys. végét.* 1. p. 121.

† *Essais sur la Végétation*, &c. Paris, 1809, p. 1.

preserve until they are lost in a mucilaginous substance, secreted under the detached epidermis. A layer of new ligneous cords is thus applied over those of the old stem, and the development of other branches still adding fresh layers, the stem is gradually increased in diameter. M. Aubert du Petit-Thouars thinks that, for the formation of branches in these plants, a vital point *(un point vital)* exists at the axilla of each leaf; but remains latent and inactive, unless peculiar circumstances occur to call it into activity; and this, he conceives, constitutes the difference between these gems and the buds which appear in the axillæ of the leaves in the great majority of dicotyledonous plants. I shall, however, soon have an opportunity of demonstrating to you that the same circumstance occurs in dicotyledonous stems; on which buds sometimes appear, that have existed in a latent state for many years; and can be traced back to their origin in the change of organization, occasioned by the frustrated effort to develop them, in the successive layers of wood which have annually added to the diameter of the stems, on which they are ultimately developed.

The development and growth of the herbaceous, solid, monocotyledonous stem is nearly the same as that of the ligneous, except that the parts are more rapidly evolved. If we trace the growth of the stem of the White Lily, for example,

springing from a full-grown adult bulb, we perceive that it first appears on the surface of the ground like a large naked leaf-bud, which, when dissected and minutely examined, consists, not only of leaves overlapping each other, but also of the rudiments of the flower and fructification. Before this has risen much above the earth, the exterior leaves separate at their apex from the others and spread themselves out to the air and light, to form those secretions which are partly deposited in the portion of the stem below them, for the purpose of affording it firmness and solidity; whilst the more succulent portion above them extends, carrying with it the bud, until the leaves, next in succession, spread out and harden it in its turn. As the stem continues to extend and the leaves alternately to expand, it thus attains the summit of its height. In this progress, the stem, as it advances, gradually loses a portion of its diameter; and a transverse section of it, near the summit, displays very few ligneous vascular cords, compared with those of one near the base; and, consequently, contains less ligneous matter. At the point, however, where the flower-stalks spring, it again thickens; and the attachment of these closely resembles that of the branches of the Dracæna.

In our demonstration of the anatomical structure of the stems of this tribe of plants, we stated

to you that those which are articulated, or knotted and nevertheless solid, form the link between the more common solid herbaceous, and the hollow or fistular monocotyledonous stems. As they display something in common with each, and yet differ from both, in some degree, in structure, so, also, they differ from both in the development of their parts. The leaves are given off at the joints, or knots only, and in general embrace the stem, or are sheathing to a certain extent: and when they protrude branches, these originate in gems formed at the joints, between the stem and the leaf, in a manner very closely resembling that in which young lateral bulbs are formed on the exterior of the laminated bulbs. These productions, indeed, may be almost regarded as lateral progeny, rather than real branches; for they shoot out radical fibrils at the lower part of a knee which they often form with the main stem; and, taking root in the earth, perpetuate the existence of the plant after the decay of the original stem. The parts of the stem below these lateral shoots increase, in a small degree, in diameter, from causes similar to those which have been already detailed as producing the increased diameter of the stem of the Dracæna; and it is in this respect chiefly that this stem differs in the manner of its growth from the culm or fistular monocotyledonous stem. This description will be better understood by refer-

ing to the marginal cut, in which 1. represents


a portion of the stem of Tradescantia *Virginica*, with two lateral shoots or branches: *a.* a young shoot, partially envelop-ed in its sheath *b.* and its origin fully displayed by the removal of the leaf in the axilla of which it is seated; *c.* another shoot, but covered by the base of the leaf, the upper part of which is cut away at *d.* In 2, which represents the same portion of stem divided longitudinally, the manner in which the buds *a. b. c.* are given off is rendered more obvious. The white longitudinal lines are the vascular cords, which always appear white amidst the green parenchyma; whilst the trans-verse septa between each articulation, being formed by the branches of these vessels assum-ing an oblique direction, appear, also, of a white colour. The vascular cords, from which the ves-sels of the shoots originate, are easily distin-guished by their greater size, and by passing di-rectly to the base of each shoot.

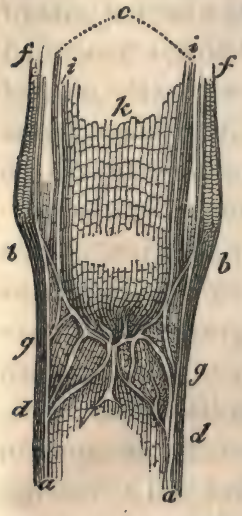
The *Culm*, as has been described, consists of

hollow articulations connected by knots; which in their growth appear to rise from within each other; the new one always carrying with it the central bud, which in the last of the series terminates in the inflorescence. The leaves are sheathing and given off only at the knots, which are solid, or rather are filled up with a dense cellular substance, containing at first a saccharine nutritious juice, which Darwin asserts to be essential to the growth of the next joint, for it is absorbed or at least disappears as that is perfected. The vascular cords, which run in straight lines throughout the length of each joint, divide as they approach the knot, forming an inosculated plexus, and send off branches to the leaf and to the new articulation, to which the cellular substance, that forms the diaphragm interposed between the cavity of each articulation, actually belongs; giving to the basis of the new joint the appearance as if it rose from a bulb. It was this appearance, as seen by the naked eye, which suggested the theory advanced by Dr. Darwin, that each joint of these stems is a distinct individual; and that the whole of a stem of any grass, Wheat for example, is a successive series of leaf-bulbs and leaf-buds produced in one year, and terminating in a flowering bulb. "At the first joint of the "stem of Wheat," says the Doctor, "on or

"within the surface of the earth, a leaf is pro-
"duced; from which rises the principal or central
"bud, and around it many new buds, which
"strike their roots into the soil. After this cen-
"tral bud, and those around it, have risen six or
"eight inches, a new leaf and a new leaf-bud
"rises on each of them, producing a second joint of
"the stem; and lastly a flower-bud is generated
"at the summit, which are all evidently *distinct*
"*vegetable beings*, as there is a division across
"the stem at each joint, which shows there is no
"connexion of the pith or brain, or spinal mar-
"row, between the lower and upper joints. That
"a new bud thus constitutes each joint of the
"stem of Wheat and other grasses is further
"evinced; first, by the existence of a leaf at each
"joint without a lateral bud in its axilla, as oc-
"curs in other vegetables: secondly, because for
"the nourishment of this new leaf-bud a reservoir
"of sweet juice is prepared in the new joint; as
"in the bulbs of many plants: and thirdly, be-
"cause the lower leaf dies, and the sweet juice is
"absorbed, as the upper leaf becomes vegete *."
Setting aside the fanciful allusions to the brain and spinal marrow, there is much plausibility in this theory; and it even appears supported by the anatomy of the knots of these stems, as far as that can

* *Phytologia*, sect. ix. 3, 1.

be perceived by the naked eye, or by the aid of an ordinary lens; but when the microscope is employed, the vessels can be traced from one joint to the other, passing through the spongy cellular diaphragm, and pursuing their course to the summit of the stem. To illustrate this, I have adjoined (see marginal cut) a plan of the vessels in the knot of the Wheat stem, as displayed by the microscope, in a longitudinal slice of a straw. In this plan the white lines *a. a.* represent the course of the vessels in the cylindrical part of the old joint running in a perpendicular direction, which they preserve up to the point *b. b.* where the leaf separates from the new articulation *c.* which is sheathed within it. At *d. d.* and between that point and *b. b.*, branches are given off, which meet in the centre of the cellular matter of the knot, and again join the vessels *a. a.* at *b. b.* where they enter the leaf *f. f.* in which they terminate. A little lower, however, opposite *g. g.* vessels are sent off, which at first are curved inwards, but soon acquire a perpendicular direction and constitute the vessels of the new joint as seen



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at *i. i.* The density of the cellular substance around the inosculating vessels constitutes the diaphragm, which is interposed between the articulations of this description of stem: and the new joint does not appear hollow at first, the cellular substance filling up its cavity as at *k.* for a short space above the knot. There can be, therefore, little doubt that the articulated culm is as much one individual as the stipe; and the truth of this opinion is not shaken by our inability to explain the object of its articulated structure. But if it be allowable to hazard a conjecture, I would say, that as the cords of vessels run in straight lines, and are comparatively remote from the surface in these stems, the enlargement at the knots is partly intended to afford space for permitting branches from these vessels to be given off to supply the new joint which originates there: accordingly we see branches added to the vascular cords as they arrive at the knots; and these, after passing through it, approach each other and disappear in the vascular cords again of the new joint; the necessity for the branches no longer existing. The original cords of the old stem actually terminate in the leaf, which is the limit of the growth of the joint; and in this respect gives some colour of truth to Darwin's theory of the individuality of the articulations. The cellular substance itself, in the knot, is probably intended

partly for supporting these additions to the vessels, and partly for the development of the new bud in the axilla of the leaf; which, notwithstanding the assertion of Dr. Darwin, occurs in the grasses in the same manner as in other plants, although in our climate it is not always evolved *. The saccharine juice, also, secreted in the knot, is more likely to be required as the first nutriment of the embryon bud (in some degree a new being †), which may be developed at this point, than to forward the growth and extension of the next joint; which is already so constituted as to be able to make use of the nutriment with which it is supplied from the soil, through the medium of the roots.

Such is the structure and the mode of growth of monocotyledonous stems. The positive features which chiefly characterize them in point of structure, are the separate vascular ligneous cords, and intermixed cellular parenchyma; but they are distinguished more strikingly by negative qualities; as, for example, those of having no proper bark, on

* In tropical climates almost all the grasses give off branches from buds formed in the axilla of the leaves; and even in this climate this occurs in Nodose Canary Grass, Phalaris *Nodosa*, and several other perennial grasses.

† I have said, "in some degree," because, even allowing the bud to be lateral progeny, yet it is, strictly speaking, an extension only of the parent, and not a new being, in the sense in which this term is properly applied to seminal progeny.

liber, no alburnum, and no medullary rays; parts which, as I shall soon have occasion to demonstrate to you, belong, exclusively, to the dicotyledonous and polycotyledonous stems. I do not, at present, attempt to detail to you either the opinions of others, or my own conjectures, relative to the manner in which the various parts of these stems are formed; nor to trace their particular functions; as we shall enter fully into this part of our subject, when we arrive at the proper moment for taking into consideration the combined functions of the root, stem, and leaves.

iii. *Stems belonging to plants, which are produced from dicotyledonous and polycotyledonous seeds,* are in every respect alike in point of structure; and, therefore, for the sake of brevity, I shall describe both under the single appellation of *Dicotyledonous stems.* In treating of these, their natural division into *woody* and *herbaceous* immediately presents itself to our attention.

A. Woody Dicotyledonous stems consist of three distinct parts, the *bark,* the *wood,* and the *pith.* They are best exemplified in trees and shrubs; but as the structure of each of these parts differs according to the age of the plant, it is requisite to examine them, both as they appear in the young plant or the shoot one year old only, and in the trunk and branches of older subjects.

If the *young shoot* of any tree or shrub, the

Horse Chesnut for example, be cut either transversely or longitudinally, the parts which have been enumerated, are rendered evident to the naked eye. If the section be transverse, it is seen to consist of a central spongy or cellular portion, which is the *pith*, enclosed within a ring of more solid consistence, which is the *wood*; and this, again, is environed by another circle of an intermediate degree of firmness, which is the *bark*. If the section be longitudinal these parts are seen, in the same order (vide fig. 1, Plate 6), extending the whole length of the shoot; the pith *a.* appears like a central column, guarded on every side by the wood *b.*, and this bounded by the bark *c.*, which forms the exterior envelope of the whole. Running the eye, however, along the section, we perceive that the bark is not continuous; but where the buds *d. e.* project, it appears as if reflected over them, while the exterior fibres of the wood enter into their substance. At the bases of the leaf-stalks *f. g.* this is not the case; for these appear as if seated upon the bark, connected with the shoot merely by the cords of vessels *h. i.* which penetrate the wood, and are apparently lost on the surface of the pith. At the summit of the shoot the pith appears to terminate, enclosed by the wood as if by an arch; whilst the bark still covering the wood mingles with the substance of the leaves which form the terminal bud *k.* In

pursuing our inquiries, we find that the bark is readily detached from the wood, *b.* and is separable into three layers; that the wood is fibrous and more compact and harder within than in its exterior part; and that the pith is evidently composed of cells, which, in the more succulent parts of the shoot, are filled with an aqueous fluid, and in the drier with air. Such is nearly the sum of the information we can obtain from an examination with the naked eye; to secure, therefore, an accurate knowledge of these parts, we must call in the aid of the microscope; and, with its assistance, let us examine each of them in the order in which they present themselves in the shoot under our inspection, beginning with the bark. In taking this course, we shall confine our actual demonstrations to this shoot: pointing out, however, and illustrating as far as possible, the varieties which have been remarked in each part, in different ligneous stems, both in their first year's growth, and in the after-periods of their existence.

*a.* The Bark. In the shoot we are now examining, which has been cut in the autumn, the bark when separated from the wood is about the sixteenth part of an inch in thickness, and appears, to the naked eye, to be composed of four very distinct parts. 1. A dry, leathery, fawn-coloured, semi-transparent, tough membrane,

which is the *cuticle*; 2. a cellular layer which adheres, although not very firmly, to the cuticle, and is named the *cellular integument*; 3. a vascular layer; and 4. a whitish layer, apparently of a fibrous texture, which is the *inner bark*; and which, as we shall afterwards find, is of a more complicated structure than the other layers. We shall now view these parts separately under the microscope.

1. The *Cuticle*. Before demonstrating the structure of this part, it is necessary to remark, that I prefer the term cuticle to that of epidermis, in reference to the exterior covering of stems and branches, in order to distinguish it from the thin unorganized pellicle which has already been described (page 93) under the name Epidermis, as one of the general components of the vegetable structure; and which is, in fact, the exterior part of the cuticle.

The cuticle may be raised from the cellular integument by the point of a knife, and this is the best method to obtain it for minute examination *. When thus separated and placed under the microscope, it appears to consist of two layers;

* Some authors recommend boiling the shoot or cutting, in order to separate the cuticle; but although it is thus readily separated, yet, the boiling coagulates and thickens its substance, rendering it opaque and destroying its natural structure.

the outer being the unorganized pellicle of true epidermis, and the inner a vascular texture, composed of minute vessels which terminate externally at the surface of the stem, and internally in the cellular integument *. These are, apparently, annular vessels with oblong pores; and, although I have never been able completely to satisfy myself that they penetrate the real epidermis, yet, they probably do so to perform the office of exhalants or of absorbents. The abrupt manner in which these vessels terminate in the cellular integument, readily accounts for the facility with which the cuticle separates from that portion of the bark †. Such is the cuticular portion of the bark of the Horse Chesnut; but the structure of this part is not the same in all ligneous dicotyledonous stems. In that of the Pear, Pyrus *communis*, it consists rather of transverse cells than of vessels, the outer series of which is covered by the real epidermis: this is the case also in the lesser Periwinkle, Vinca *minor*, in which there are three series of such cells; in the Laburnum, Cytisus

* Vide Plate 6, fig. 2, *a*.

† It was probably this vascular part of the cuticle, which led Du Hamel (*Phys. des Arbres*, liv. 1. c. ii.) to describe the vegetable epidermis as a tissue of delicate parallel fibres inosculating at regular intervals, or united by lateral fibres, so as to constitute a network, the meshes of which are filled up with a thin, transparent pellicle.

*Laburnum*, it is composed of the epidermis simply covering a layer of an irregularly cellular or spongy character; in the Laurustine, Viburnum *Tinus*, of one layer of cells covered by the epidermis; and the same is the case in the Vine, except that the cells are extremely minute, and oblong in the length of the stem, having the appearance of vessels in the transverse section. These and similar varieties in the structure of the cuticle account for the want of coincidence in the descriptions of authors.

The true epidermis or exterior layer of the cuticle is necessarily cribriform, whether it act as an exhaling or an absorbing surface; and the manner in which the pores are arranged, does not differ less, in different plants, than the structure of the interior layer. It is frequently studded with hairs, glands, and prickles; but, as these are not peculiar to stems, their particular structure shall be demonstrated, when we treat of the general vegetable appendages. In young and succulent shoots, the cuticle is generally almost colourless, and semi-transparent, transmitting the green colour of the exterior part of the cellular integument over which it lies; but it becomes opaque and coloured by age, or rather on losing its vitality; for, as it is annually reproduced, on the ligneous stems under consideration, the old layer, if it does not fall off, cracks and is pushed

outwards by the increase of the diameter of the stem; and the accumulation of such layers forms the rugged surfaces of stems, as for example of the Elm, the Oak, and the majority of trees *. In the greater number of instances it cracks vertically, and is pushed outwards with a portion of the cellular integument by the new epidermis, which can be brought into view by removing these rugged portions. In others it splits horizontally, and the new cuticle is formed immediately under the old, which, after a time, detaches itself in fragments; or, there is a succession of cuticles, which, although one is formed every year, yet do not separate annually, but occasionally only, in multiplied layers, that can, however, be readily detached from each other, as in the *Currant* and the *Paper Birch*. Some trees, the *Plane* for example, annually throw off the cuticle at once, in large flakes; and in this respect, such plants resemble those reptiles that cast their skins or their crusts, as the snake, the spider, and the lobster.

2. The *Cellular integument*. On carefully raising the cuticle of the young shoot of the Horse Chesnut, we find under it a cellular layer; which, in a transverse section of the stem placed under

* In Plate 6, fig. 10, *a*. represents a microscopic view of the various layers which form the rough cuticle of an old stem of the Lilac, Syringa *vulgaris*; the innermost only of which retains its vitality.

the microscope, is seen to consist of two distinct parts, both cellular, but nevertheless different. The exterior, or that on which the cuticle immediately reposes, appears to be composed of a dark green, semiorganized pulp, in which the cells are irregular both in their dimensions and form (vide Plate 6, fig. 2, *b.*), and has somewhat of the aspect, as Mr. Keith aptly expresses himself, of "a "distinct and separate epidermis in an incipient "state, rather than a true and proper pulp:" while the interior is less coloured and composed of regular hexagonal cells (Plate 6, fig. 2, *c.*), the sides of which are perforated and frequently studded with small granular bodies. It is the exterior layer of the cellular integument, which is the seat of colour of the young twig, and the green hue of which is transmitted through the yet semitransparent cuticle: its appearance, and the fact that it is annually reproduced, led Mr. Keith to believe that it is really the next year's cuticle in an incipient stage of organization. But the vertical direction of the cells, while those of the cuticle are horizontal, is sufficient to overturn this opinion, (Plate 6, fig. 7, *a.* 1. 2.) These two portions of the cellular integument are particularly noticed by Mirbel, who denominates the exterior the herbaceous tissue, and the interior the parenchyma; and conceives, with much probability, that the deeper green colour of the latter

depends on the exposure of its juices to the light and on the resinous nature of these juices. He regards the whole of the cellular integument, also, as a glandular body serving to separate the transpirable matter from the other fluids *; an opinion which I shall have occasion to notice more particularly when we investigate the functions of the stem. The cells of the interior portion, in the young shoot of the Horse Chesnut, are very regular hexagons, except in those places where there is any pressure, or where the adjoining parts require a variation of form, when a change takes place; but, independent of these circumstances, the pure hexagonal form does not prevail in the stems of every species of the natural tribe of plants under examination. Thus in Privet, Ligustrum *vulgare*, the cells are variously formed, some being nearly circular, others rudely elliptical, and some very obscurely heptagonal: in the Elder, Sambucus *nigra*, they are equally irregular; in the Common Lilac, Syringa *vulgaris*, the proportion of real cellular matter compared with that of the semi-organized pulp is small, and the cells, which are of an oblong figure, are completely filled with minute amylaceous granules; and this is the case, also, in the Laburnum, Cytisus *Laburnum*, in which, however, they

* *Elémens de Physiologie végétale,* 1ere partie, p. 103.

are regular hexagons: in the Pear, Pyrus *communis,* they resemble globular utricles: and in the Rock Rose, Cistus *Ledon,* they are irregular oblong hexagons. Such are the diversities of figure of these cells; but it is still a question whether the membrane of which they are composed be single or double, as I formerly remarked (page 75), in describing the cellular texture among the general vegetable components? Senebier and Link are both of opinion that each cell is a separate utricle, completely distinct from those which are in contact with it, and consequently that the partitions are double on every side. Link further contends * that there are no visible organic pores in these partitions, the fluids passing from the one to the other by a double filtration; and that the appearance of pores is occasioned by small amylaceous granules scattered over their surfaces. It is certainly not easy to determine this question as far as regards the double or single nature of the cellular membrane, although I am disposed to believe it is double; both from the appearance which it presents under the microscope, and also from the greater facility which such a supposition affords of explaining the origin, and the hexagonal figure of the cells, a point which shall be discussed in its proper place; but, if

* Vide ROMER, *Collect. Botanic. facs.* 1. p. 163.

any confidence is to be placed in the microscope, there can be no doubt of the existence of the cellular pores. That many of the cells, however, are filled with minute particles, is perfectly evident; and the number of these is always greater where a branch is given off. Their use is yet unascertained, but it is not improbable that they are of a nutritive nature, and deposited in the cells to be dissolved by the ascending sap for the evolution of new parts. Independent of these particles, the cellular integument is filled both with coloured and colourless secreted juices; and it is very probable that this part performs some changes on the sap thrown into its cells, similar to those effected in the leaf.

The cellular integument is partially destroyed, and reproduced, a great part of the old portion being pushed outwards with the cuticle which is annually detached; while new cells are added to that which remains at the time the new cuticle is produced.

3. *Vascular layer.* Imbedded in the cellular integument and impinging on the internal surface of the bark, are distinct bundles of entire vessels, each of which is so arranged as to present, in the transverse section of the stem under consideration, a semilunar aspect *; and, in the

* Vide Plate 6, fig. 2, *d*.

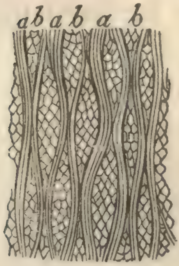
longitudinal section, that of a fascis of flexible cords, readily separable from each other, and from the surrounding cellular substance*; which is condensed where it comes in contact with these bundles. These vessels are supposed to convey downwards the proper juice of the plant, elaborated from the sap, by the action of the light and air in the leaf; and this opinion is supported by the fact, that it is from them the milky juice of the Fig-tree and the coloured juices of other plants exude, when the stem is transversely divided. In some stems, as, for example, that of Laburnum, Cytisus *Laburnum*, the vascular bundles coalesce, and form nearly one continuous layer or circle around the wood; and in others, although they do not actually coalesce, yet, they approach so close as almost to assume the same character. As the stem increases, these vascular bundles become impervious, and are pushed outward with the cellular integument, giving place to a new layer which is annually produced.

4. *Inner bark.* Immediately under the vascular bundles, we find another layer† which constitutes the internal boundary of the bark. In the transverse section of the stem of the Horse Chesnut now before us, it appears under the microscope

* Vide Plate 6, fig. 7, *a*. 3.

† Plate 6, fig. 2, *e*. and fig. 7, *a*. 4.

to consist of the extremities of longitudinal fibres closely united together; and, in the tangental section, these fibres are seen running in a waving direction and touching each other at certain points only so as to form oblong meshes, which are filled with cellular matter. The nature of this structure will be better understood by referring to the magnified marginal plan, in which




*a. a. a.* represent the reticular arrangement of the longitudinal fibres, and *b. b. b.* the cellular meshes. This layer is denominated LIBER, a name imposed from its having been employed to write on before the invention of paper. As the network formed by the dividing threads of the meshes is not readily dissolved in water, whilst the cellular matter which fills them up is remarkably soluble, the liber of some plants, for example the Daphne *lagetto*, when soaked in water and afterwards beaten, forms a very beautiful vegetable gauze; which may be used as an article of dress. A coarser specimen of this gauze, or lace, is seen in the bark of many of our indigenous trees, particularly the Oak, when it has been long exposed to the weather, after being separated from the trunk. This regular arrangement, however, of the longitudinal texture of the liber, is not found in every instance; for in the Fir and some other

trees the longitudinal threads are seen lying nearly parallel to one another, without any meshes or intervening cellular matter. Like the other parts of the bark, the liber is annually reproduced. The old layer loses its vitality, and is pushed outwards by the new; the accumulation thus formed constituting what botanical writers have called the cortical layers, which Malpighi supposed derived their origin from the older bark.

The vitality of the stem of dicotyledonous plants is more conspicuous in the liber than in any other part. If the bark be wounded, or a portion of it be removed, layers gradually extend themselves from the liber on each side of the wound until it is closed up; but, as this is not effected in one year when the wound is extensive, and as the new layers are thrown out by the liber only which is annually renewed, the cicatrix, if the healed portion can be so named, always resembles a hollow cone, the base of which is the exterior of the trunk. The union of a graft, or of a bud taken from one tree and implanted on another, succeeds only when the liber of the bud, or the graft and that of the stock is placed in immediate contact; the union in these instances closely resembling that which occurs when two raw surfaces of a living animal body, or of two distinct animals, are retained for some time in contact. Grew, Malpighi, Du Hamel, and others

supposed that the liber annually changes, by hardening, into the alburnum or young wood, an opinion which is still maintained by some of the ablest phytologists *; but which I shall afterwards prove to you is founded upon mistaken principles. It is through the liber, however, that the matter in which the new wood is formed, which annually augments the diameter of the trunk and branches, is secreted; and hence the importance of this portion of the bark.

Such is the structure of the bark of the stems of woody dicotyledons; and that of the root does not materially differ from it; any difference depending, perhaps, altogether on the medium in which these two parts are situated. In the bark the secreted juices of plants, and consequently their medicinal qualities, are chiefly deposited; but the consideration of the functions of this part and its properties must be deferred, until the whole of the structure of the stem has been described.

*b.* The Wood. Pursuing our investigation in the young stem of the Horse Chesnut; when the whole of the bark is removed, we find, immediately under and slightly adhering to it, a firmer and more compact substance, which, both in a longitudinal and a transverse section, ap-

* "Le liber endurcie, de verdâtre qu'il était, devient blanch-"âtre, et prend le nom d'aubier." Mirbel, *Elémens de Phys. vég.* t. i. p. 106.

pears to constitute a cylinder, enclosing a column of spongy cellular matter or pith. This is the wood. It has been regarded, in reference to the vegetable, as answering the same end as bone in the animal body; but, except in its property of giving firmness and support to the plant, the analogy does not hold good. It is at first soft and vascular, and is then called *Alburnum*; but it afterwards becomes hard, and, in some trees, is of a density almost equal to that of iron. In a transverse section of our stem of Horse Chesnut, it appears, to the unassisted eye, a continuous circle of a homogeneous structure, of a very light straw colour exteriorly or near the bark, and greenish interiorly, or where it is in contact with the pith; but in some other trees, as for example the Laburnum and the Elder *, this circle appears traversed, at nearly regular distances, by rays of an evidently different structure. These are found, however, to exist also in the stem of the Horse Chesnut, and in every other woody dicotyledon when it is examined by a magnifying glass; and they are observed in the soft wood, or alburnum, as well as in the hard and most perfect wood. These two distinct parts, which constitute the wood, may be described under the names *Concentric* and *Divergent* layers †.

* Vide Plate 6, fig. 3. 4. 5.

† These names are adopted by Mr. Keith (*System of physiological Botany*), and are more expressive of the parts they are intended to designate, than any others which have been employed.

Placing a very thin transverse section of the stem of Horse Chesnut under the microscope, the wood no longer appears solid and compact; but of an irregular reticulated texture †. In this state, however, the concentric and divergent layers are readily distinguished; the open spaces in the former being evidently the transverse orifices of divided longitudinal or vertical cells and vessels, whilst those in the latter are the lateral openings of horizontal cells ‡. Let us now examine separately the minute structure of each of these parts as they appear in the stem of one year's growth.

1. The *Concentric layers* consist apparently of longitudinal fibres, which are, however, apparently not solid, but narrow tubes or oblong cells, the sides of which are thick and nearly opaque, and of vessels of different kinds. These are arranged parallel to each other, except where they are separated by the divergent layers, as may be seen in a thin tangental section of any stem placed under the microscope; and is rudely displayed in the marginal plan,

in which *a. a. a. a. a.* represents

† Vide Plate 6. Fig. 2. * represents the first state of the soft wood or alburnum, *f.* the more perfect wood, and *h.* the orifices of the large vessels of the wood.

‡ Vide Plate 6, fig. 2. *g.*

the longitudinal fibres or oblong cells; *c. c. c.* the vessels which in the Horse Chesnut are porous, and *b. b. b.* the exterior ends of divergent layers. In the *alburnum*, the walls of the concentric tubes are tender and transparent; but by the deposition of ligneous matter in the membrane of which they consist, and in the tubes themselves, they become opaque and firm; and according to the degree of this, the wood is more or less dense, hard, and tenacious. Other matters, also, are deposited in this part of the woody texture; such for example as Guiaic in that of the Guiacum *officinale*, colouring matter in the Logwood, Hæmatoxylon *Campechianum*, and even silex, which has been extracted from the Teak wood, Tectona *grandis*, by Dr. Wollaston. The vessels of the concentric layers are chiefly porous and annular, and their section produces the openings observed in the transverse section of any stem*; but besides these, in the circle of the wood of the first year's growth, a circle of spiral vessels surrounds the pith †. These are, however, justly regarded by

* Vide Plate 6, fig. 2. *h.* and fig. 8. *a. a. a.* The tubular nature of the oblong cells, forming the concentric layers, is rendered evident in this section of the common Elder, fig. 8. at *b. b.*; and the distinct character of the divergent layers at *c. c.* Leuwenhock, in 1680, first delineated the porous vessels of the wood. Vide his *Epist. Physiolog.* p. 14. 19.

† Vide Plate 6, fig. 7. *d. e.* 7, 7, 7. In this figure, also, the first, or half-organized state of the alburnum, is represented between *b. c.*; and the vascular structure of the perfect wood

Mirbel not as vessels of the wood; but of a distinct sheath lining the wood, which he has denominated l'étui médullaire; and there is undoubtedly some reason for this distinction, inasmuch as these vessels have not been detected in the wood, but always in immediate contact with the pith. I shall more particularly examine this opinion before describing the structure of the pith.

2. The *Divergent layers* * consist of flattened masses of cellular substance, which cross the concentric layers at different parts, and, separating the bundles of longitudinal tubes of which they consist from each other, produce the reticulated arrangement seen in the tangental section of any stem; the oblong tubes and vessels forming the tissue of the network, the meshes of which are filled up by the cells of the divergent layers. The individual cells, which are narrow and horizontal in their length, extend in series from the centre to the circumference of the wood; and consequently form nearly right angles with the tubes of the concentric layers †. They communicate with each other by pores; so that fluids may readily pass through the whole series, and of

between *c. d.*, the smaller vessels being marked by the figure 5, and the larger by 6, showing distinctly their porous and annular structure.

* Dr. Grew was the first author who described these layers under the name of *insertions*.

† Vide Plate 6. fig. 7. *. *.

course transversely through the wood; and Mirbel remarks that, "in many coniferous trees the di-"vergent rays are not cellular; but consist of ho-"rizontal tubes which extend from the medulla or "pith to the bark*." Whether they are cellular or tubular, the layers, or masses, are flat, or in plates, with the edges placed vertically, and thicker in the centre than either above or below, appearing therefore of a lozenge shape (see marginal plan, p. 331) when vertically divided; whilst in their transverse section they display a slight inclination to the wedge form †. They are much more delicate in their structure than the concentric layers; and readily dissolve, like the common cellular texture, so that when a thin tangental slice of wood is macerated in water, the divergent layers are decomposed and leave the meshes of the concentric layers empty, displaying the appearance of a network or lace similar to that formed by the macerated liber.

From the cellular texture of the divergent layers, they are regarded by some authors as processes of the pith or medulla; and hence have been named medullary rays; and Mr. Keith observes, they are "apparently nothing more than "the vesicles or cellular tissue of the pulp that "originally existed in the alburnum now deprived

* *Elémens de Phys. vég.* 1re partie, p. 110.

† Vide Plate 6, fig. 2. *g*.

" of its parenchyma; but still filling up the in- " terstices of the concentric layers, and binding " them together like a cement." But there is little difficulty in demonstrating the error of both these opinions; for, examining the alburnum in a very early stage of its formation at the moment it is passing from the gelatinous state in which it is first deposited, we find the rudiments of both the concentric and divergent layers already assuming the form which they afterwards maintain. Were any further reason required to prove that the divergent layers do not originate in the pith, it would be found in the fact, that many of them cannot be traced to the pith; although the more conspicuous of them traverse the whole of the wood, from the pith to the bark.

Such is the structure of wood in the stems of one year's growth of ligneous dicotyledons; and it is found nearly of the same structure in the root: a fact, which is rendered evident, not only by the microscope, but also to the unassisted eye, by the decomposition of the divergent layers in the ligneous part of roots which have been dug up and long exposed to the action of the atmosphere. The concentric layers, longer resisting the action of the weather, remain after the divergent have disappeared, and display a beautiful network, more or less open in its meshes, according to the density or sponginess of the wood.

Wood in its soft state, or that in which it forms the outer circle in every ligneous dicotyledonous stem and branch, is, as has been already mentioned, named *alburnum*. While it continues so, it is endowed with nearly as much irritability as the liber; and, as shall be afterwards fully described, performs functions of great importance in the vegetable system; but when it becomes hard these functions cease, and in time it loses even its vitality; not unfrequently decaying in the centre of the trunk of trees; which, nevertheless, still flourish and put forth new shoots as if no such decay existed. To carry on, therefore, the functions of the wood, a new circle of it is annually formed over the old; and thus, also, the diameter of the trunk and branches present, by the number of these annual zones, a pretty correct register of their age, each zone marking one year in the life of the part *. There are, however, exceptions to the criterion thus afforded of the age of the plant, for circumstances may occur to prevent the zone from being formed of a thickness which will be perceptible after a few years have passed over, and it is pressed between other zones. If the summer

* Vide Plate 6, figures 3, 4, 5, which represent sections of the same stem, in the first, second, and third year of its growth; and fig. 6. which displays two zones, as they are seen in a longitudinal section of the stem of the Elder.

be unusually cold, or if the leaves of the tree or the shrub happen to be much devoured by caterpillars, it gains very little that season in diameter. From the same cause the zones are also of unequal degrees of hardness: but, independent of the comparative density of each, the hardness of the whole increases with the age of the tree, so that they are hardest in the centre, and less and less hard as they approach the circumference. The outermost layer, being *alburnum*, is always soft, and continues so until another layer is formed over it; but if the tree be barked the alburnum assumes the apparent character of wood in the same year; and hence it has been recommended to bark trees the year before they are intended to be cut down. "The German foresters," however, "have proved that wood treated in this "manner is less elastic, and is more easily in-"jured by humidity and insects *;" which I conceive is owing to the natural change of alburnum into wood not depending on a simple hardening or condensation; but on such a deposition of ligneous and other particles in its texture, as tends to increase the cohesive attraction of all its parts, and consequently to augment both its hardness and its elasticity; while the exposure of the alburnum, by stripping off the bark,

* Mirbel, *Elémens de Phys. vég.* 1ere partie, p. 110.

produces merely a simple condensation of the solid matter, a hurried crystallization of the salts, and a hasty consolidation of the other secretions. Indeed, when wood acquires its firmness by the natural means connected with its growth, it is a well-known fact that the hardest is always of the slowest growth; as exemplified in the comparative hardness of the wood of the Oak, which is of very slow growth, compared with that of the Willow or Horse Chesnut, which are trees of rapid growth; and even in that of the wood of the same tree when growing in a dry and in a moist situation.

Much difference of opinion has existed among Phytologists regarding the origin of each successive layer of wood. Linneus conceived that it is formed from the *pith*, and added internally; but the absurdity of this opinion must be immediately obvious to any one who examines the transverse section of any stem or branch more than two years old. Dr. Hales supposed that it is formed from the zone of the prior year, by the horizontal dilatation of the vessels, and "the "shooting of the longitudinal fibres lengthways, "under the bark, as young fibrous shoots of roots "do in the solid earth*;" an hypothesis which has had almost as few followers as that of Linneus. Malpighi taught that the *liber* is annually trans-

* *Vegetable Staticks*, p. 340.

muted into *alburnum* *; an opinion which was afterwards supposed to be fully established by the experiments of Du Hamel and of Dr. Hope, and is still maintained by Mirbel †. The first object of Du Hamel was to ascertain whether the new layer of wood was formed by the bark, or by the former layer of wood. He raised a portion of the bark of a growing tree, and introduced under it a piece of tin foil, over which he carefully bound down the bark ; and, after the wound was healed, allowed the tree to remain in the ground for some years. He then cut it down, and found layers of wood on the outside of the tin foil ; but none had been formed between the foil and the wood with which it had been placed in contact ‡. This experiment, although it was decisive of the fact, that the new layer of wood is not formed by the old layer which preceded it, yet has been justly objected to by Mr. Knight as by no means confirming the opinion of Malpighi regarding the transmutation of the liber into wood; and the same objection may be applied to the following experiment of Dr. Hope, detailed by Sir J. E. Smith, on the authority of his son, Dr. Thomas Hope. " A longitudinal incision

* *Anat. Plantarum.*

† " La transformation du liber en aubier est prouvée par " l'observation microscopique et par l'expérience." *Elémens de Phys. vég.* p. 106.

‡ *Phys. de Arbres,* l. iv. c. 7.

" several inches in length was made in the bark of " a branch of Willow, three or four years old, and " the bark loosened, so that it might be slipt " aside from the wood in the form of a hollow " cylinder, the two ends being undisturbed. The " edges of the bark were then united as carefully " as possible, the wood covered from the air, and " the whole bound up to secure it from external " injury. After a few years, the branch was cut " through transversely. The cylinder of bark was " found lined with layers of new wood, whose num- " ber, added to those in the wood from which it " had been stripped, made up the number of rings " in the branch above and below the experi- " ment *." But if these experiments do not prove the truth of Malpighi's opinion, they completely disprove the hypothesis of Hales; and throw great light upon the fact, that the alburnum is actually formed from the secretion deposited by the vessels of the liber; an opinion which has been fully established by the experiments of Mr. Knight †.

* *Introduction to physiological and systematical Botany,* chap. iv.

† It is but justice to say, that although Dr. Hales states it as his opinion that " the new zone of wood is formed by the " shooting of the longitudinal fibres lengthways under the bark, " as young fibrous shoots of roots do in the solid earth ;" yet that he afterwards remarks, " we may observe that nature has " taken great care to keep the parts between the bark and wood

Before, however, entering into the details of Mr. Knight's doctrine, it will be proper to notice that of Dr. Grew, who conceived that a new ring of sap-vessels is first generated in the mucilage thrown out between the bark and the wood, to which he gave the name of *Cambium*; and this ring of vessels, lining the inner surface of the liber of the former year, is converted into a new layer of liber that ultimately splits into two portions, the outer of which forms the new layer of bark, and the inner the new layer of wood. Notwithstanding the inconsistency of this hypothesis, in supposing that the mere separation of the two portions of the liber could produce, in one of these, a new organization and properties, so distinct as those which the wood possesses from the liber, yet it has been characterized, by a late able writer on vegetable physiology, as "perhaps more "conformable to fact" than any other *. Du Hamel made several experiments to ascertain its truth. He passed threads of fine silver wire through the bark of a tree, some near the outer part, or towards the epidermis; others near the liber, others through the liber itself; and others between the wood and the liber. After

"always very supple with slimy moisture, from which ductile "matter the *woody fibres*, vesicles and buds are formed." *Vegetable Staticks*, p. 340.

* Mr. Keith.

some years, when the tree was cut down, those that were placed towards the epidermis were found covered by a thin, decayed, and friable crust only; those that were placed near the liber were now among the external cortical layers; those that were passed through the liber were now imbedded in the wood; as were those, also, that had been placed between the wood and the liber *. At first sight this experiment appears perfectly conclusive of the truth of Grew's opinion; but, when we consider the probability that the wood and the liber are formed at the same time; for the vital action which is capable of forming the one is undoubtedly equal to the generation of both; the difficulty of drawing an accurate inference from such an experiment is obvious: and if our reasonings must be hypothetical, there is certainly more wisdom in deciding in favour of that conjecture, which explains the effect by simple and direct means, than of that which supposes two causes, the one consequent on the other; and the second involving a difficulty as great as that which it is intended to explain.

But the true explanation of the phytological fact under consideration, was reserved for Mr. Knight, whose experiments and observations have settled almost every doubt upon the subject. Mr. Knight could not avoid admitting that the experiments of Du Hamel and of Dr. Hope were

* *Physique des Arbres*, l. iv. c. 7.

sufficiently satisfactory, so far as regarded the fact that the presence of the bark is necessary for the formation of the new zone of wood; but he denied their conclusions; and it was still essential to ascertain whether the wood is transmuted liber? or, if not, whether the matter of which it is formed be a secretion from the bark, or supplied by some other of the vegetable organs? That it is not transmuted liber is evident from the dissimilarity of the liber and the alburnum. Thus, according to Mr. Knight *, the commencement of the alburnous layers in the Oak is distinguished by a circular row of very large tubes, which appear in spring, arranged in ridges in a gelatinous mass, beneath the cortical vessels; but such tubes are not found in the bark of the tree, which would be the case were the alburnum a transmutation of the liber. The bark of the Wych Elm (Ulmus *montana)* also is so fibrous and tough that it may be formed into cords, while that of the Ash (Faxinus *excelsior)* is very fragile and not at all fibrous; nevertheless the wood of both these trees, and consequently the alburnum, is nearly alike †. As convincing a proof also is the simple fact, that the layer of alburnum is often more than twice the thickness of the bark. But the question was settled by the following experiment of Mr. Knight.

* *Philosophical Transactions*, 1805. † Ibid. 1808.

He cut out a ring of bark from the stem of an Apple tree, and another from that of a Crab tree, which were particularly distinguished from each other by the colour of their wood. He then transposed these rings, applying and fixing, by means of a firm bandage, the bark of the Crab tree quite round the uncovered part of the stem of the Apple tree, and that of the Apple tree round the stem of the Crab tree. The air was excluded from both by a plaister of bees wax and turpentine, and covered with well-tempered clay. The inner surface of the Crab tree bark had sinuosities that corresponded with elevated parts of the alburnum of the tree from which it was taken, occasioned by the former extension of many branches; but that of the Apple tree bark was smooth. In a short time a vital union took place between the applied pieces of bark of both trees, and the bark and alburnum of the trees on which they were bound; and before the end of the ensuing autumn "it appeared evident that a layer of "alburnum had been, in every instance, formed "beneath the transposed pieces of bark, which "were then taken off." "Examining," continues Mr. Knight, "the organization of the alburnum, which had been generated between the "transposed pieces of bark of the Crab tree, and "which had formed a perfect union with the al-

"burnum of the Apple tree, I did not discover any "traces of the sinuosities I had noticed; nor was "the uneven surface of the alburnum of the Crab "tree more changed by the smooth transposed "bark of the Apple tree. The newly generated "alburnum, beneath the transposed bark, ap- "peared perfectly similar to that of other parts of "the stock, and the direction of the fibres and "vessels did not in any degree correspond with "those of the transposed bark *." Nothing, in my opinion, can be more decisive of the question than this experiment; for, although Mr. Knight himself modestly suggests that it is not "calculated to prove that the *newly generated* "*bark* was not converted into alburnum;" yet it is not probable that the merely transposing the bark of one tree to another would alter the original features of the liber of the transferred portion in so short a period as one season, if such a change should even afterwards occur; of which, however, we have no evidence. The obvious conclusion therefore to be drawn from this experiment is, that although the alburnum is generated through the medium of the bark, yet, it is decidedly not transmuted liber.

The opinion of Mr. Knight is, that the bark deposits the alburnous matter; but that the leaves

* *Phil. Trans.* 1808, Part I. p. 104-5.

are the organs in which this matter is elaborated from the sap; or, in other words, that the alburnum is generated from the cambium, which is part of the proper juice of the plant, formed by the exposure of the sap to the light and air in the leaf, and returned from it by the vessels that pass down from the leaf into the interior bark, by which it is deposited. To determine this point, he removed narrow circles of bark from shoots of Apple trees, "leaving a leaf between the places where "the bark was taken off; and on examining them "frequently during the autumn," he found that the diameter of the shoot between the insertion of the leaf-stalk and the lower incision was as much increased as in any other part of the tree; but when no leaf was left "on similar portions of in-"sulated bark, on other branches of the same "age, no apparent increase in the size of the wood "was discoverable *." No other inference, than that the leaf is the essential agent in producing the increased diameter of the wood, could be drawn from this experiment: and Mr. Knight further found that where the deposition of the proper juice returned from the leaf is greatest, that is, at the points where the returning vessels enter the inner bark, there the formation of alburnum is observed to take place in ridges cor-

* *Phil. Trans.* 1801, P. I. p. 2, p. 335.

responding to the number of the vascular bundles. The fact, indeed, that the leaf is essential for the formation of wood, had been observed by Dr. Hales, who took off circles of bark half an inch in breadth, at several places, from two thriving shoots of a dwarf Pear tree, leaving on all the remaining intervening ringlets of the bark, except one, a leaf-bearing bud, which produced leaves the following summer. Each ringlet, on which a bud was left, grew and swelled below the bud, or at its lower edge; but that one on which no bud was left "did not increase at "all *:" but he drew a very different and less probable conclusion from his experiment, which it is unnecessary to mention in this place.

The above-mentioned experiments of Mr. Knight readily explain why trees and shrubs, the leaves of which are destroyed by caterpillars, form scarcely any new wood in that season; and, indeed, every one who has ever pruned a tree, or shortened a growing twig, must have observed that the part above the last leaf always shrivels and dies, while all below it continues to live and increase in diameter: and we observe the same thing in the lower part of the stem of a young tree, when a portion of the bark has been gnawed off by sheep, or accidentally destroyed. The part above the wound continues to

* *Vegetable Staticks*, p. 145, fig. 28, 29, 30.

augment in diameter, as represented at *a* in the


marginal cut, because it is supplied by the alburnous matter furnished from the leaves; but that below it, *b*, ceases to grow, and continues in the same state, the communication by the interior bark between it and the foliage being completely destroyed. From the same cause, also, the pith of a stem is thrown apparently out of its centre, for some distance below the point where a branch is given off; a circumstance which I shall very soon have occasion more particularly to notice*.

The only objection of any weight which has been advanced against Mr. Knight's theory, is founded on the fact, that when a stem is wholly, or in the greater part stripped of its bark, and the denuded surface excluded from the action of the air, a glary fluid is exuded from the alburnum, or soft wood, which gradually becomes organized and cellular. Detached spots of bark are thus reproduced, and, gradually extending, coalesce, until the stem is again clothed with

* Vide Plate 6, fig. 6. which displays, moderately magnified, a longitudinal section of an Elder (Sambucus *nigra)* of two years growth, with a luxuriant branch of the same age :— *a.* the trunk has the pith *c.* in the centre, except below the branch *b.* where the additional wood *e.* augments the diameter of the stem on that side.

a new bark, capable of performing all the functions of the original. This fact was first observed by Du Hamel. But Dr. Hope's experiment proves that a similar matter is exuded from the liber, when the bark is detached from the wood; and Mr. Knight observed that in this case it becomes sooner organized than when it is exuded from alburnum; and as we cannot conclude that the new bark is first generated from the former year's alburnum, and then the new alburnum from this newly formed bark, the only mode of getting over the objection is, by supposing that, under that state of circumstances which as it were obliges the wood to form a new bark, the descending juice from the leaves being impeded in its course downwards through the bark, finds its way into the alburnum in much greater quantity than is required for the ordinary purposes of the plant in that part of its structure; and the alburnous vessels taking on a retrograde action, it is thrown out in the manner described at different points over the denuded trunk. This opinion is supported by analogy in the animal body, on which, when one organ is destroyed, its function is performed by another. We are, therefore, fully warranted in adopting Mr. Knight's theory, as far as it maintains that the wood is formed from the proper juice which descends from the leaf through the inner bark; but, in doing so, there are some

points which have been overlooked by Mr. Knight, and to which it is necessary to direct your attention.

In explaining his theory, Mr. Knight seems to imply that the whole of the change which the sap undergoes is effected in the leaf, and that the liber is the mere medium of transmission of the alburnous matter. But if, as we must admit is most probable, the whole of the secretions of the plant are produced from the same proper juice elaborated from the sap, by its exposure to light and air in the leaf; and consider the great diversity of these; it is more likely that some alteration takes place in the bark, previously to the cambium being thrown out by its vessels; and, consequently, we must admit the force of Mr. Keith's suggestion, that it is "possible the proper juice "may receive its final degree of modification in "the bark itself*." It is by such an admission only that we can satisfactorily explain the fact observed by Mr. Knight in one of his experiments, that a small quantity of wood was generated even at the lower lip of an insulated portion of bark, on which there was neither bud nor leaf†. It is also necessary for the sake of those unacquainted with physiological reasonings, to remark that it is not

* *System of physiological Botany*, vol. ii. p. 229.

† *Phil. Trans.* 1803.

to be supposed, from the term deposition of alburnous matter which Mr. Knight employs, that nothing more is necessary for the formation of the alburnum than the deposition of that matter. For although alburnous matter may be justly said to be generated from the sap after its elaboration in the leaf, whether we designate it by the term alburnous matter, or cambium, or proper juice, yet it is merely the pabulum; the organization of the alburnum, or the transmutation of the cambium into its cellular and vascular texture, being the result of the vital principle operating upon it, in a manner which we do not understand, and not of any simple coagulation, or attraction, or chemical affinity of its parts, in any way similar to what would take place in the same matter, wherever deposited, if deprived of vitality. The simple fact, therefore, is, that the sap is changed into proper juice in the leaf, and returned into the bark, where part of it being poured out in a gelatinous form between the liber and the wood, there becomes the raw material from which the new zone of wood, in its state of alburnum, and the new layer of liber, are manufactured by the vital principle inherent in the living plant.

Such is all that is necessary to be known, in the present stage of our investigation into the origin of the annual zones of wood, by which the diameter of ligneous dicotyledonous plants is

augmented. Many important points, indeed, relating to the inquiry, and involving other hypotheses, still remain to be examined; but these must be deferred until I again bring the question, as it is connected with the general theory of the growth of the vegetable body, under your consideration *. The following simple facts, therefore,

* Although it is unnecessary to load the text with any further details of the various hypotheses, which have been advanced in explanation of the origin of the annual zones of wood, which increase the diameter of ligneous dicotyledons, yet it may not be improper to give here a slight sketch of that of M. Aubert du Pétit Thouars, which has for some years past divided the opinions of the French Botanists. He regards each gem which exists at the axilla of a leaf, as an embryon resembling, in some respect, that contained in the seed; and which, to effect its evolution, draws its nourishment from the succulent parenchyma on the bark on which it is seated, and with which he supposes it to have an immediate communication. As soon as the gem begins to be evolved, it sends down fibres, which our author regards as the roots (véritables racines) of the gem; and these growing and extending by the organic power (qui, comme l'electricité et la lumière, semble ne point connoitre de distance), pass down between the wood and the bark from the gem whence they originate to the roots of the tree, taking up, as nutriment (la matière de leur accroissement), in their passage the viscous fluid, or cambium, which at this season is found between the wood and the bark. The sum of these radical fibres constitutes the new layer of wood, which appears in a concentric circle, owing to the leaves, and consequently the gems, whether they are opposite or alternate, rising on every point of the circumference of the

relative to the origin and increase of the concentric zones of wood, observable in the transverse section of any tree or shrub of more than one year's growth, and which has sprung from a seed

stem or shoot. In the same manner, he supposes the liber is formed by an equal elongation of the fibres of the interior bark of the gem; so that each gem has thus a double communication with the root of the tree. The latter part of our author's opinion closely resembles that promulgated by Dr. Darwin, who supporting the theory of the individuality of buds, thus expresses himself:—" The bark is only an intertexture " of the caudexes of the numerous buds, as they pass down " to shoot their radicles into the earth" (*Phytologia*, 4to. 1800, chap. i. § 1, 2, 3); but he also so far maintained the opinion of Du Hamel, as to suppose that as these caudexes form a new bark over the former one, that of the last year is transmuted into alburnum. M. Aubert Du Petit-Thouars explains the formation of the medullary rays by supposing that the fibres which, according to his doctrine, constitute the new layers of wood and liber, determine the formation of a certain quantity of parenchyma, which is deposited interiorly by the ligneous fibre, and exteriorly by the fibres that form the new liber. (*Essais sur la Végétation considérée dans le Développement des Bourgeons*, Paris, 1809, 2e Essai.) I shall not endeavour to point out the very hypothetical nature of this doctrine; but merely observe, that, with the exception of the remark that each gem is a distinct embryon, the whole is founded upon assumption; and that it is utterly destroyed by the simple fact, that isolated spots of bark and alburnum are formed on decorticated stems, which cannot be the roots descending from the gems, unless we suppose that these have penetrated the wood and again protruded at the points where the new patches of bark and alburnum appear.

with two or more cotyledons, are to be regarded as fully established:

1. That the proper juice descending from the leaf through the vessels of the bark, and poured out between it and the wood of the preceding year, is the material from which the new wood or alburnum is formed.

2. That the organic power, or vital principle, inherent in the plant, transforms this viscous fluid into cells or vessels, or regularly organized alburnum; the divergent layers being formed at the same time as the vertical or concentric layers.

3. That under certain circumstances, such as the entire decortication of a stem, the lateral communications, which exist throughout the vegetable structure, may conduct the descending juices through the wood, so as to be thrown out in detached spots on its surface; and there be transformed into new bark and alburnum.

The use of the wood to the plant, exclusive of its power of supporting and elevating the buds with their leaves and fructification in the atmosphere, is chiefly confined to its soft or alburnous state. In this state it is endowed with a high degree of irritability. But if it be freely exposed to the atmosphere during a few hours only, all vegetation for ever ceases on that surface; and, although the bark may close above it, and new wood be formed over it, yet, no vital union

takes place, and the new wood will always remain distinct*. In this state, also, through its tubes the sap is raised to the summit of the highest trees; and, according to Mr. Knight, when this function ceases in winter, it becomes "a reservoir "of the sap or blood of the tree, as the bulbs of "the Hyacinth and Tulip, and the tuber of the "Potatoe certainly do of the sap or blood of these "plants;" an analogy which is good; but we must remark, in making this admission, that it is not the sap, but the proper juice *(succus proprius)*, which is there laid up, and is dissolved by the first ascending sap in the spring.

The alburnum does not attain its entire thickness at once; but continues to increase during the greater part of the summer, at least till after the midsummer shoots are protruded; and even, if circumstances occur to stop its progress, such for example as a week of very cold weather in the middle of the season, two layers may be formed in the same year; an event not unlikely to happen in this variable climate, and which throws an uncertainty on the mode, which has been already alluded to, of determining the age of trees by counting the number of the concentric zones of

* In this new wood the divergent rays are distinctly seen; a sufficient reason, as Mr. Knight remarks, for believing that they are not processes of the pith.

wood displayed in the transverse section of a stem. As the alburnum changes into wood it loses its irritability; but an unexceptionable theory of the means by which this change is effected, is still a desideratum in vegetable physiology. The opinion that the lignification is the consequence of the mere loss of fluid parts, and the approximation of the solid, cannot be admitted as correct; because, in this case, the drying of the alburnum even after a tree is cut down, would give it the consistence and characteristics of perfect wood, which is not the fact. I am inclined to believe, that the ligneous matter is deposited in a manner somewhat analogous to the deposition of the phosphate of lime in bones; and that this deposition continues to be effected long after the alburnum assumes the character of wood. The heart wood, even of an old tree which is sound, contains some moisture as long as the tree continues to grow, which can only be accounted for by supposing that it still lives *, and, consequently, is in some degree under the control of the organic power; and, as a lateral communication is preserved between the exterior and the interior of the stem by means of the divergent rays, there is no improbability in supposing that a sufficient supply of proper juice finds its

* Darwin (Phytologia, xviii. § 2, 12.) asserts that the heart or internal wood is not alive; but this is not the case, for the whole is alive whilst the tree remains sound.

way to the innermost layer of wood, until that has received its final degree of induration. I know of no observations which tend to prove that the concentric zones are diminished in thickness as they increase in solidity and density, which would be the case, did they shrink or suffer any compression; and if it be true that no such change takes place, their progressive induration can be explained only by admitting that there is a continual deposition of new matter. The truth of such an opinion is further confirmed by the change of colour, which the alburnum undergoes in passing into the state of perfect wood. With regard to the period at which the wood attains its final degree of induration, I would say, with Mr. Keith, that perhaps no layer has acquired this state until "such time as the tree has arrived at "its full growth*."

Returning to our shoot of Horse Chesnut, if we scoop out the pith from the ligneous cylinder that encloses it, we perceive this is lined with a thin green layer or coating; which, to the unassisted eye, appears to resemble in its structure rather the cellular integument of the bark than any part of the surrounding wood. This is the MEDULLARY SHEATH *(etui médullaire)* of Mirbel and the French Botanists: for, although it was

* *System of physiological Botany*, vol. ii. p. 230.

first noticed by Dr. Hill, who named it Corona, yet, it has been overlooked or confounded with the wood, or the alburnum, by almost every succeeding British Phytologist, until Mr. Knight's attention was directed to it in searching for his central vessels. It is readily distinguished, in either a transverse or a longitudinal section of many stems, by its green colour, which appears deeper as contrasted with the dead white, the more usual hue of the pith which it surrounds; but it is also easily traced in the succulent dicotyledonous stem as soon as it is evolved from the seed, separating the pith from its herbaceous investiture.

When viewed under the microscope the medullary sheath appears to be composed of a cellular substance, in which are imbedded longitudinal layers of spiral tubes *. It is not easy to comprehend the meaning of Mr. Knight, when he speaks of another description of vessels as being found here, to which he says "the spiral "vessels are every where appendages," and which he names central vessels, "to distinguish them "from the spiral tubes and the common tubes of "the wood†." In the stems which I have exa-

* Vide Plate 6, fig. 7. in which the space from *d.* to *e.* represents the appearance of the medullary sheath in a longitudinal section of an annual twig of Horse Chesnut; 7. 7. 7. the bundles of spiral vessels; and 8. the parenchyma, or green cellular lining of the sheath.

† *Phil. Trans.* 1801.

mined, the spiral vessels are seen in some instances detached, or not immediately accompanied by any other description of vessels, and in others they are accompanied by either cribriform or annular vessels according as the one or other of these are the common vessels of the alburnum and wood. Thus, in longitudinal and in tangental sections of the medullary sheath of the Horse Chesnut, the spiral vessels are accompanied with the cribriform vessels only of the wood; and such is, also, the case in the Elder (Sambucus *nigra)*, and in the Lilac (Syringa *vulgaris)*. In the Elastic-gum Fig tree (Ficus *elastica)*, the sheath of which is not distinguishable by colour, the spiral vessels are seen close to that part of the first year's wood, which touches the pith, and consequently in the situation of the sheath; but they are not immediately accompanied by any other vessels: those nearest to them, however, are cribriform, like the larger vessels of the wood. In the Medlar (Mespilus), in which there is, likewise, no evident medullary sheath, the spiral tubes, which are very numerous, are accompanied by the common vessels only of the alburnum: and in the Cinnamon (Laurus *Cinnamomi)* the accompanying vessels are annular, such being the vessels of the alburnum and the wood. The cells of the medullary sheath (Plate 6, fig. 7, *d. e.* 8.) are narrow and oblong; and, therefore, when it is not coloured it is scarcely

distinguishable from the wood, except by the spiral vessels; which have not yet been discovered in any layer of formed wood subsequent to the first; for their apparent existence in stems and branches of several years' growth, is owing to the lignification of the medullary sheath. Grew and Hedwig, however, have represented them as existing in the wood; but, although I have searched for them in every species of wood, yet I have not been able to detect them; and as the same result has followed the investigations of Du Hamel, Mirbel, Knight, Mr. Keith, and others, I am inclined to regard my conclusion as correct. The cells which are between the layer of spiral vessels and the pith (Plate 6, fig. 7, *d. e.* 8.); and which are the site of the colouring matter, when this part of the stem is green, as it is in the example now before us, have a cribriform structure.

The spiral vessels of the medullary sheath vary in their arrangement, and thus the widely separated bundles they form in the Elder, give the canal of the pith a furrowed character; in the Pear tree their arrangement produces an irregular pentagon; and this is, also, the case in the Oak; while in Laurel-leaved Magnolia, M. *grandiflora*, the bundles are seen at the distance of four or five diameters from each other, and projecting forwards, so as to seem imbedded as it were in the pith. But, whatever

may be the arrangement, it appears to be in a great degree regulated by the disposition of the leaves, into which the spiral vessels in every instance direct their course, leaving for that purpose the medullary sheath, and traversing the wood, a little below the insertion of each leaf.

As the medullary sheath forms the only partition between the bark and the pith in the tender succulent shoot, before the ligneous matter is deposited, and is in its texture lax, and incapable of affording sufficient support to the delicate coats of vessels, such as are found in the alburnum, if these were distended with ascending sap, the vessels that run through it are of a different structure from those of any other part of the vegetable. The elastic thread of which these spiral vessels are formed is tough, and possesses irritability; and being stimulated to action by the effort of the sap to dilate the diameter of the vessel, contracts in its length in each coil alternately, and after each contraction again returns to its first state, producing a vermicular motion, which enables these vessels to conduct forward the sap. Thus:—the contraction in length of the portion of the thread which forms the first coil, lessens the diameter of that portion of the tube, and hence the fluid contained within in it will be displaced and moved either upwards or downwards; but as the resistance opposed to its return, or movement

downwards, is the greater owing to the pressure of the ascending sap, it must necessarily advance; and this contraction being repeated in every successive coil, the fluid is moved forward with a sufficient impetus; while the new quantity of sap which supplies the place of that carried forward, and which rushes into the coil at the instant of its relaxation, forming the basis of resistance to the return of the portion before it, and at the same time exciting a renewal of the contraction, its progression must be uninterrupted. I should be anticipating what I have to say on the general ascent of the sap (or, as it has been erroneously termed, its circulation), were I now to explain the means by which this fluid is raised through the ligneous parts of a tree, until it arrives at the succulent twigs, in which alone the spiral vessels are active; and it is, therefore, here merely necessary to add, that I believe these to be the only vegetable vessels endowed with contractility, or which act in any manner analogous to the arteries of animals. If this hypothesis be maintainable, the spiral vessels are the sap vessels of the succulent stem and the annual shoot of dicotyledonous ligneous plants; and their spiral structure is essential for the performance of their conducting function, in the spongy medullary sheath, or cellular parenchyma in which they are imbedded. How long they continue to act as sap vessels it is impossible to conjecture; but they

may maintain their irritability, and consequently their contractility, for two or more seasons, or as long as the medullary sheath remains succulent; although, as it is not necessary for the progression of the sap that they should act by alternate contraction and dilatation, after the alburnous or ligneous vessels are completed, it is probable that they lose these properties, after the first year of the life of the stem or of the twig.

If we inquire what are the opinions of other phytologists respecting the functions of the spiral vessels, we find Malpighi regarding them as bronchia, or air-vessels *, and the same opinion is supported by Grew †, Hales ‡, and Du Hamel §. Grew, however, believed that they acted as sap-vessels in the wood ||, in which, as I have already stated, he fancied he had detected them; and Du Hamel once suspected that they might contain highly rarefied sap. The supposition that they are air-vessels, probably originated from their always appearing empty when examined; but on the same account the animal arteries were regarded as air-vessels by the ancients and their followers, until

* *Anat. Plantarum.*

† *Anatomy of Plants*, fol. edit.

‡ *Vegetable Statics*, chap. v.

§ *Physique des Arbres.*

|| His words are, "in the wood the sap ascendeth only by "the air-vessels." *Veg. of Trunks*, chap. i.

the discoveries of the immortal Harvey demonstrated them to be blood-vessels. The opinion that they contain air only, is still maintained by Mr. Knight, who supposes them to be appendages to another set of vessels, which he denominates *central*, and through which he supposes the sap ascends as soon as it arrives at the bud or succulent shoot, "aided by the spiral vessels *." I have however demonstrated to you that the spiral vessels are unaccompanied by any others, at least in all those trees which I have examined, and are even at some distance from the alburnous vessels in the annual shoot of many plants. Mr. Knight, it is true, in another essay †, endeavours to explain the meaning of his term central vessels, by saying that they are the same as the tubular tissue of M. Mirbel; but, as the spiral vessels form part of Mirbel's tubular tissue, which besides comprehends all the other species of vegetable vessels, this attempt at explanation only renders the subject more confused. Mr. Keith, in criticising Mr. Knight's explanation, has fallen into a curious mistake regarding Mirbel's opinion of the vessels which carry the sap. He says, "If we regard their (the central vessels) re-"spective functions, they can correspond only to "the small tubes, as it is by them alone, accord-

* *Phil. Trans.* 1801. † Ibid. 1807.

"ing to M. Mirbel, that the sap ascends." *(Syst. of phys. Bot.* vol. ii. p. 119.) Now, Mirbel's words are, "la sève monte par les gros vaisseaux." (*Elémens*, t. i. p. 208.) The cells of the medullary sheath are, indeed, oblong, and, therefore, somewhat tubular, and to these probably Mr. Knight refers; but, admitting this, we cannot see in what manner the ascent of the sap through these cells can be aided by the spiral vessels, the bundles of which are, in many instances, placed at the distance of three or four diameters from each other, and consequently the intermediate cells are beyond the sphere of their influence. Mr. Knight's opinions on this subject have certainly much less weight than they usually and most deservedly possess.

Grew, as I have already stated, first suggested the idea of the spiral vessels acting as sap vessels, and Du Hamel supposed he had detected them in the performance of this function. Hedwig * also asserts, that he observed the sap issuing from the orifices of the spiral vessels in a horizontal section of the stem of the Pumpkin, Cucurbita *Pepo*, and the squirting Cucumber, Momordica *Elaterium*; and Senebier †, more lately, remarked the same occurrence in a section of the stem of the Sago

* *Fundamentum Hist. Nat. Muscorum frondosorum*, Lip. 1732, p. 55.

† *Phys. vég.* t. i. p. 107.

Palm, Sagus *farinifera*. Dr. Darwin may perhaps, however, be regarded as actually the first who taught that the spiral vessels convey fluids; and he suggested the idea, which, with some modifications, I have adopted, of the manner in which they carry forward their contents. "It is easy," says he, "to conceive how a vermicular or peri- "staltic motion of the vessel, beginning at the low- "est part of it, each spiral ring contracting it- "self, *till it fills up the tube*, must forcibly push "forward its contents without the aid of valves *." He, however, considered them absorbent vessels; and erroneously supposed that they pass down the trunks of trees from the caudex of each bud, to the roots. Finally, Mirbel † regards the spiral vessels as sap vessels; whilst Mr. Keith considers the reformed opinion of Grew the most correct, namely, that they transmit not only air but sap ‡.

*c*. The MEDULLA or PITH. Returning to our shoot of Horse Chesnut, we find the tube which is formed by the wood and lined with the medullary sheath, as has been already described, filled with a white, dry, very compressible, spongy substance:—this is the *Medulla* or *Pith*. In the succulent state of a stem or a twig, it is turgid with aqueous fluid; but before the wood is perfected it

* *Phytologia*, sect. 11, 8.

† *Elémens de Phys. vég.* 1[ere] partie, p. 205.

‡ *System of phys. Botany*, vol. ii. p. 120.

becomes dry and spongy; except near the terminal bud, or where branches are given off, in which places it long retains its moisture.

The form of the pith is regulated by that of the cavity it fills, which in the majority of instances is nearly circular; but to this there are many exceptions. Thus, in a horizontal section of a young stem or twig of the Elder, Sambucus *nigra*, and the Oriental Plane, Platanus *orientalis*, we find it circular, but furrowed by the bundles of spiral vessels of the medullary sheath. It is oval in the Ivy, Hedera *Helix*, and the Ash, Fraxinus *excelsior*; irregularly oval and furrowed in the Oriental Plane, Platanus *orientalis*; triangular in the Oleander, Nerium *Oleander*; pentangular in the Oak, Quercus *Robur*; four-sided, with the angles obtuse or tetragonal, in common Lilac, Syringa *vulgaris*, and yellow flowering Horse Chesnut, Æsculus *flava*; pentagonal in the Walnut, Juglans *regia*, and hexagonal in the common Dogwood, Cornus *sanguinea*. M. de Beauvois is of opinion that the situation of the leaves on the stem regulates the form of the tube which the pith fills, an opinion which M. Mirbel * regards as fallacious; but it is nevertheless true, that in the horizontal section of many stems, the form of the medulla differs at, and immediately under the

* *Elémens de Phys. vég.* 1ere partie, p. 111.

places where the leaves are seated, from what it is in the intermediate spaces. In the Lilac, for example, the obtuse tetragon becomes an ellipsis near the insertions of the leaves, which are opposite; while each angle of the Oleander is lengthened into a horn or process. But besides these diversities of form, the pith varies in diameter in other respects. In the young tree, of a few inches in height, it is smallest at the basis of the stem, largest in the middle, and smaller again at the summit; and in the growth of each future year, nearly the same variations in its diameter are observable.

The pith, in the majority of ligneous dicotlyledons, is longitudinally entire; but in some, the Walnut for instance, it consists of a succession of transverse diaphragms intersecting the hollow cylinder of the wood, with the intervening spaces empty *. In others the continuity of the medullary column is broken by ligneous plates, which proceeding from the side of the central tube, either partially intersect it or completely partition off portions of it, as in several of the Magnolias; while in others, again, it is merely a spongy sheath, lining the interior of the cavity, as in the stem and branches of Woodbine, Lonicera *Periclymenum*. Where the branches are

* Vide Plate 6, fig. 11.

given off from a stem, a thread of medulla, in some instances, separates from the central column, and entering the branch, is gradually augmented to a diameter proportionate to that of the branch *. Such a circumstance led M. Aubert Du Petit-Thouars † to describe the medulla at the base of every bud, as an inverted cone, the apex of which originates from the pith of the branch on which the bud appears; but in general this is not the case, the pith commencing in the bud itself, which originates at the surface of the stem; and hence no direct union exists between the

pith of the branch and that of the stem (see marginal figure). In the annual shoot, the wood shuts up the canal of the pith at its extremity, as soon as it ceases to grow for the season, as is seen in the longitudinal section of our shoot of Horse Chesnut, immediately under the terminal bud ‡; and thus isolates it from the shoot of the next year. In many plants this forms a kind of woody partition, which marks the limit of the growth of each year in the length of the stem; but in others it is absorbed, the continuity of the pith being, appa-

* Vide Plate 6, fig. 6. representing a cutting of the common Elder; in which *d.* the pith of the branch *b.* is united by a small thread to *e.* the pith of the main stem *a.*

† *Histoire d'un Morceau de Bois*, p. 153.

‡ Vide Plate 5, fig. 15.

rently, uninterrupted from the root to the apex of such stems. Those partitions are almost always present when the pith is composed of distinct plates, as in the Walnut, or of a spongy sheathing membrane, as in Woodbine.

The colour of the pith, in the succulent shoot or in the young plant, is green, which, as the cells empty, changes to white; but to this there are some exceptions. Thus it is yellow in the Barberry, Berberis *vulgaris;* pale brown in the Walnut, Juglans *regia;* fawn-coloured in the Sumach, Rhus *Coriaria;* and pale orange in yellow-flowered Horse Chesnut, Æsculus *flava;* but it is more frequently coloured in the caudex of the root than in the stem.

Placing a thin slice of pith, taken either from a vertical or a horizontal section of our shoot of Horse Chesnut, or of any other plant, under the microscope, it appears to consist of hexagonal cells *, which are larger and more regular in the centre than near the circumference †. In very young stems and succulent shoots, these cells are filled with an aqueous fluid, and closely resemble the cellular integument ‡; but, in older stems and twigs, they are found empty, or, more accurately

* The cellular structure of the pith was first pointed out by Grew in his work on the *Anatomy of Plants*, fol. 1682.

† Vide Plate 6, fig. 2, *k*.

‡ Vide Plate 6, fig. 2, *c*.

speaking, filled with air. The cells retain the hexagonal form in their empty state; but in some, as the Walnut, this is destroyed in the lamellæ, into which the pith then separates; and the same occurs in the interior of the medullary sheath of Woodbine, and similar hollow stems. In the greater number of plants no vessels are perceptible in the pith; but in some, entire vessels conveying proper juice are present, as in the Gum-elastic Fig tree, the proper juice of which is seen exuding from different points of the pith in a horizontal section of the stem: and, in all plants, the cells communicate with each other by means of organized pores, which are visible under the microscope. M. Aubert Du Petit-Thouars has lately affected to regard the medulla as deserving that name only after the cells become empty, naming it parenchyma in the early or succulent stage of its existence*: but this is at best a useless refinement; for, although I am not prepared to admit, with Mr. Keith †, that there is an essential difference between the membrane composing the cells of the parenchyma or pulp, and that forming those of the pith, yet the insulated and enclosed situation of the pith is sufficient to obtain for it the dignity of

* " Ce n'est que par l'extraction des sucs qu'elle (la Mo-" elle) contient qu'elle est devenue Moelle." *Essais sur la Végétation*, p. 205.

† *System of phys. Bot.* vol. i. p. 324.

being a distinct organ in every stage of its existence.

To enter at present upon the explanation of the formation of the pith, would be anticipating our inquiries into the general theory of vegetation, a part of our subject for the discussion of which we are not yet fully prepared. Regarding, however, the mere mechanical causes which possibly operate in producing the hexagonal form of the cells, I may remark that, if the gelatinous pulp, which constitutes the earliest state of the pith, assumes the form of globules as the first effect which the operation of the vital organizing influence produces on it; it is easy to conceive that, from the individual inflation of these occasioning them to press in every direction upon one another, within a certain limit, each globule will necessarily acquire an hexagonal form. In this state the flat surfaces of the enclosing membrane of each globule which are in immediate contact, uniting and acquiring firmness, while the contained fluid is dissipated and air admitted, the cavity it occupied will remain as an hexagonal cell; and of such is the dry pith constituted. To produce this effect, however, the following circumstances are necessary: 1. The membrane which divides each cell from those adjoining it, must be double, which Link *

* *Secunda Dissert.* in Romer's *Collect. Bot.* fascic. i. p. 163.

and Kieser * have demonstrated to be the case †. 2. This membrane must be cribriform, such as I have described it, when seen under the microscope, to permit the aqueous fluid to pass readily through it, and to admit the air into the cells to supply its place. But it is necessary to remark here, that this fact, although supported by the observations of Sprengel, Mirbel, and others, is positively denied both by Link and Kieser; but, as it was requisite for those who denied the porosity of the membrane to state how fluids can be transmitted from one cell to another, Link has advanced the unphilosophical suggestion, that this is effected by a double filtration through invisible pores: and the ingenious Mr. Ellis, who gives credit to Kieser's observations, is forced to admit that this filtration can be accomplished, "consistently with the integrity of the cellular texture, only by the exercise of the alternate functions of secretion and absorption ‡." 3. The mass must be free from any external pressure, which would, eventually, destroy the regular form of the cell.

It is not easy to conjecture by what means

* *Mém. sur l'Organization des Plantes*, p. 91.

† We may also regard as an analogical proof a fact lately ascertained by Dr. Barclay, that each side of every cell in the honeycomb is double, or composed of two plates of wax. Vide *Wernerian Trans.* vol. ii.

‡ *Supplement to the Encyclop. Brit.* vol. i. Part 2.

air is introduced into hollow ligneous stems; but, probably, in those in which the pith is sheathing, as in the Woodbine, the union between the utricles may be less intimate in the centre, and the air insinuating itself between them, while the cells are emptying themselves, compresses their sides together and separates them; and extending itself in the length of the stem, forms it into a hollow tube. In others, as the Walnut, it may be introduced laterally, in separate quantities, at different points at the same time, and these dilating, compress the horizontal portions of the emptying cells between them, so as to produce the medullary plates, which characterize that and similar stems.

Phytologists have not differed more on any subject than in assigning the functions of the pith. When we reflect that Cæsalpinus, who lived in the sixteenth century, taught that the pith is less essential to the life and growth of a tree than the bark *, it is astonishing that writers of so recent a period as Dr. Darwin and Sir J. E. Smith, should be found maintaining the accuracy of the ancient opinion, that the pith is to the vegetable what the brain and spinal marrow are to the animal body †. Darwin's imagination led him

* *De Plantis.* Flor. 1583.

† Such was also the opinion of Linnæus, *Amœn. Acad.* vol. iv. p. 372.

even so far as to believe that it furnishes "the "power of motion, as well as of sensation to the "various parts of the vegetable system *." Hales and Linnæus also regarded it as the seat of the vital energy of the plant †; and Mr. Lindsay, of Jamaica, "thought he demonstrated the medulla "in the leaf-stalk of the Mimosa *pudica*, or Sen-"sitive Plant, to be the seat of irritability;" nor "can I," says Sir J. E. Smith, "see any thing "to invalidate the opinion ‡." It would, nevertheless, be no difficult task to prove the untenable nature of these doctrines, were they not completely destroyed by the experiment of Mr. Knight, who abstracted more than an inch of the pith from the shoot of a vine, above and below a leaf and bud; both of which, "with the lateral shoot an-"nexed, continued to live, and did not appear to "suffer much inconvenience; but faded a little "when the sun shone strongly upon them §." Now the life of the shoot, even admitting with Darwin, for the sake of argument, that each bud has a sen-

* *Phytologia*, xviii. 2, 13.

† Linnæus, like Darwin, compared it to the spinal marrow.

‡ *Introd. to phys. and syst. Bot.* chap. vii.

§ *Phil. Trans.* 1801, p. 338.

Mr. Keith gives a quotation from Theophrastus to show "that this experiment had been performed, and the result as-"certained," even in the time of that naturalist. *System of phys. Bot.* vol. ii. p. 211.

sorium of its own ||, could not be supported under such a circumstance, did any analogy exist between the medulla of plants and the spinal marrow of animals. Grew and Malpighi believed that the functions of the pith are the same as those of the cellular integument, which they regarded as the organ for elaborating the sap into nourishment for the support of the plant, and to give origin to future buds; an opinion which Mr. Keith regards as the best founded of any yet advanced, with the exception of that part of it which relates to the origin of buds. Du Hamel, on the contrary, considered the pith in common with the general cellular texture, as merely intended to hold together the various parts of the plant; and lastly, Mr. Knight has supposed that "it forms a "reservoir to supply the leaf with moisture, when- "ever an excess of perspiration puts that in a "state to require it ‡." There is certainly much plausibility in Mr. Knight's suggestion; and it is not, in my opinion, destroyed, as has been sup-

|| "The pith," says Darwin, "communicates to the leaves "on each side of it, but not to the new buds in the bosoms of "those leaves; because those new buds are each an indi- "vidual being, generated by the caudex of the leaf, and must, "therefore, possess a sensorium of its own." *Phytologia*, § xviii. 2, 13.

‡ *Phil. Trans.* 1803, p. 349. A similar opinion is advanced by Plenck, in his Physiologia Plantarum.

posed, by the remark of Sir J. E. Smith, that "all the moisture in the *medulla* of a whole "branch is, in some cases, too little to supply "one hour's perspiration of a single leaf*;" for Mr. Knight could never mean to assert that the fluid in the medulla is intended to supply the entire loss of moisture from perspiration in the leaf, although it might make up the excess. But a more tenable objection to this hypothesis may be deduced from the fact, that the succulent twig perspires nearly as much as the leaves themselves; droops also, like them, from an excess of perspiration in sultry weather; and is again, in the same manner, revived by the check given to that excess in the night, or by a fresh supply of moisture to the roots. What then, it may be asked, is the use of the pith?

In answering the above question, I may remark, that as it is more easy to discover the defects of an hypothesis, than to suggest one; and as none is so unlikely to discover the errors of a new opinion, as its proposer, it is very probable that that which I am about to hazard on this subject, may be found as defective as any of those we have criticised.

* *Introd. to phys. and syst. Bot.* p. 41. Mr. Keith concurs in the objections of Sir J. E. Smith, regarding them as "fatal to Mr. Knight's hypothesis." *Syst. of phys. Bot.* vol. ii. p. 24.

If we examine a tree in the first stage of its growth, or a fresh shoot, we shall be satisfied that the alburnum and bark form so very small a portion of their diameter, that, were there not some means of extending the surface of these parts, there would be neither sufficient space for the formation and arrangement of the vessels essential to their future existence; nor a sufficient support to maintain the plant in its erect position, or the shoot in its projection. To supply these purposes the pith is given to young plants and shoots; for, its cells being filled with an aqueous incompressible fluid, both extension and support are thus afforded by it, as long as these are required, or until the first ligneous zone is fit to allow the next zone of alburnum to be formed on it, and consistent enough to afford sufficient stability to the plant. When this takes place, the moisture passes from one cell to another until it is altogether carried off, leaving the pith in the dry spongy state in which it is found in the older stems and branches. The comparative diameter of these stems and branches depends equally on the evolution of the pith; for, in moist seasons, when these push out thicker and more vigorous than usual, we find their mass consist chiefly of pith; and the ligneous circle, although much widened, yet, not containing a proportionate increase of substance. In such shoots also we have another proof that it is the turgidity of the medullary cells with

aqueous fluid, which gives them firmness, and enables them to rise to the great height to which they often attain in so short a period, without any curvature; for, on examining the pith, the cells are found not more numerous, but merely larger than in an ordinary shoot. As soon, however, as the first circle of wood is formed, no subsequent increase of diameter can be attributed to the pith. If these remarks be correct, the following must be regarded as the functions of the pith: 1st, to afford the surface necessary for the formation of the first layer of wood; and 2d, to give a degree of firmness to the succulent stem and recent shoot, which they would not otherwise possess, before the bark and alburnum acquire sufficient consistence for that purpose.

But is the pith of use only in the succulent shoot? If my idea of its functions be correct, its utility to the plant must cease as soon as the first circle of wood is perfected; and it is indeed not easy to conceive in what manner it can be useful after it has become dry. Mr. Keith remarks, "it "is essential to vegetation in all its stages*;" but even admitting that it is, as he and Malpighi believe, an organ of elaboration, we must suppose that all vegetation ceases in every annual shoot at the termination of the season in which it is

* *Syst. of phys. Bot.* vol. ii. p. 213.

evolved, before we can accord with his position; for it is during that period only that the pith is essential in trees and shrubs. But although its functions cease, yet the pith still remains a part of the trunk of the oldest trees, as long as these remain sound. Some authors, among whom we find Willdenow *, Mr. Keith †, and Sir J. E. Smith ‡, assert that it disappears altogether, obliterated "by the increasing solidity of the wood." Darwin § supposes that it is either absorbed or imbued with ligneous matter, so as not to be distinguishable from wood; an opinion which Mr. Knight combats, affirming that its place "is never filled with "wood ‖;" while others contend that it never varies, being the same in the old trunk as in the young branch. Let us examine in what these opinions are correct.

In stems, the wood of which is of a close texture, and the divergent layers very thin, no obliteration of the pith can take place, nor even any compression of it occur, after the case of wood which encloses it is perfected; and, on close examination, it can readily be detected in the oldest sound stems of this description; but,

* *Principles of Bot.* trans. p. 251.

† *Syst. of phys. Bot.* vol. ii. p. 213.

‡ *Introd. to phys. and syst. Bot.* p. 39.

§ *Phytologia*, xviii. 2, 13.

‖ *Phil. Trans.* 1803.

as in almost every old stem, it has acquired the colour of the wood, and is comparatively so small a point in the diameter of a large trunk, it is easily overlooked. In a transverse slice from the centre of a very old Oak, now before me, the medulla is distinctly seen of the same size and figure usually found in the young stem, although its colour is nearly as dark as that of the surrounding wood, and the cells are altogether obstructed; and in the stem of a Nectarine, twenty years old, also now before me, the same state of the pith is observable. In both, the cells appear obliterated, even when examined by a good lens; but when a very thin slice is placed under the microscope, in a drop of pure water, the hexagonal character of the cells is perfectly distinguishable if the section be transverse; while, if longitudinal, not only the difference of form between the real pith cells and those of the medullary sheath is perceptible, but the spiral vessels are seen, filled with a dark-coloured resinous matter. In such stems, therefore, the pith is neither compressed, obliterated, nor converted into wood. But when the ligneous matter is of a loose texture, or, instead of forming a continuous circle, it is in separate columns, as in broad-leaved Birth-wort, Aristolochia *Sipho*, and the divergent rays are very large, the pith, although it is never completely obliterated, yet, is considerably compressed and

2

altered in form, in stems even of a few years' growth. The future state of the pith, therefore, varies; and is altogether regulated by the character of the wood which encloses it.

Such is the general anatomy, or, more strictly speaking, phytotomy of ligneous dicotyledonous stems. Almost every species of tree and shrub, however, has something peculiar to itself, but these are more connected with the arrangement, than with the structure of the parts.

# LECTURE VIII.

## ORIGIN AND ATTACHMENT OF BRANCHES; STRUCTURE OF LIGNEOUS ROOTS; AND OF HERBACEOUS DICOTYLEDONOUS STEMS.

Whether we regard branches merely as divisions and subdivisions of the stem, or more correctly, at least as far as regards their origin, as distinct individuals, its lateral progeny, we find their structure to accord in every particular with that of the stem. The description of the structure of the trunk is consequently applicable to the branches; and we have now, therefore, only to investigate the nature of the connexion between these parts: tracing the branch from its earliest state, or long before it is visible to the eye, till it is fully extended, and has itself become the parent of future branches.

Every branch is formed in a bud or gem; and every bud, except perhaps the terminal one, and such as appear on roots, and constitute suckers, originates in the axilla of a leaf*; to trace, therefore, the origin of the branch, is in fact to trace

* Some buds, as, for example, those of the Plane and the Sumach, are generated in the centre of the base of the footstalk of the old leaf; but this is a mere modification of the axillary bud.

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that of the axillary bud; and this may be done most readily in the succulent shoot of any tree or shrub in early spring, as, for example, of the common Lilac, which is at this time (March 26th) just expanding its leaves.

In the shoot now under consideration, one inch only in length, and on which none of the real leaves, except the three first pairs, are yet expanded, we cannot perceive, on pulling off those nearest the base, that is, the intermediate between the scales of the bud from within which the shoot has protruded and the real leaves †, any appearance of a bud in their axillæ, even when the sight is aided by a good lens: neither is any seen at the attachments of the second pair. At the third, however, we observe by the aid of the lens, immediately above the laceration produced by tearing off the leaf, a minute elevation, resembling a semitransparent vesicle depressed in the centre; which, under the microscope, appears to be a lobular body, with a small green speck in the central depression (see Plate 7, fig. 1, *a*) ‡. This is the rudiment of the

† The distinguishing characteristics of real leaves, and of those which appear first on a new shoot, shall be pointed out when we examine the external structure of buds.

‡ In this figure, which represents a thin tangental slice of the shoot very highly magnified, *a.* displays the appearance of the embryon germ within the bud; and *b.* the lacerated base of the footstalk of the removed leaf: *c.* is the natural size of the

bud and germ *, and consequently of the future branch. To examine the structure minutely, let us place a longitudinal and a transverse slice of the shoot under the microscope.

In the portion of the longitudinal slice of which a highly magnified drawing is now before us (see Plate 7, fig. 2), we perceive the section *a.* of one of the lobes, situated at the point where the footstalk of the leaf *b.* separates from the stem *c.* The small speck at the base of the lobe appears now an obtuse, pyramidal, insulated body; while nearly all the cellular matter above *e.*, which is apparently the line of separation between the system, if I may be allowed the expression, of the bud and that of the leaf, seems directed towards it. The bundle of spiral vessels, *d.*, passes upwards to supply the leaf; but neither the lobe nor the speck has any vessels, unless we suppose that some from the liber *f.* above it, are given off for its supply; a circumstance which, however, is conjectural only, as none is perceptible. The whole of the cellular substance, connecting the

slice. The whole of the cuticle in this young state of the branch is studded with small pedicillated glands, which exude a viscid tenacious fluid.

* It is necessary, before proceeding, to explain the meaning of these terms. The *bud* or *gem* is the pyramidal body, as it appears on the surface of the stem or branch covered with its scales; the *germ* is the rudiment of the young branch, and leaves contained within these scales.

lobes with the pith *g.* is more opaque than in any other part, from its cells being filled with small amylaceous granules; but whether these are deposited by the vessels which convey the proper juice from the leaf above them, it is impossible to decide. The chief fact established by this view of the parts, is the connexion between the cellular matter of the lobes of the gem, and that of the pith, the medullary sheath, the bark, and the liber, in the succulent shoot; while, nevertheless, the germ itself appears a distinct body. In the transverse section (Plate 7, fig. 3) this connexion betwixt the lobes *a.* and the pith *e.* is still more apparent; for neither the spiral vessels *d.* which appear like a circle of dark spots surrounding the pith in every other place; nor the alburnous matter *c.* which accompanies them, interfere to prevent this union. In this section, also, the distinct nature of the germ, notwithstanding its connexion with the surrounding parts, is rendered very evident. As the bud advances in growth, it gradually assumes somewhat of a pyramidal form; and the organization of the germ within it, that is, of the new branch and leaves, commences. Towards the end of summer, the lobes begin to appear as opposite scales, from amidst which the apex of the germ, covered by other scales, is observed protruding; whilst in a longitudinal section placed under the microscope, the rudiments of the new

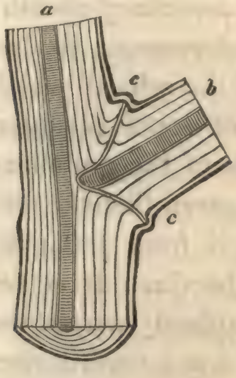
branch can be traced; for it is now obscurely marked by the deposition of alburnous matter, which being paler and more transparent than the rest of the bud, is seen separating the cellular substance to constitute the future pith (see Plate 7, fig. 6, *a.*), from (*b.*) that which is to form the bark. But no spiral vessels are yet perceptible; the alburnous circle is mere semitransparent matter; and the pith is distinguishable from the cellular substance in which the germ is formed only by the paler alburnous matter surrounding it *. The progress of the organization advances a little in autumn; but is not perceptible during winter, and it is not until the following spring that the embryon branch is very conspicuous. At this period, in the Lilac, the plant before us, it is seen rising as it were from the medullary sheath, in which the spiral vessels seem to originate; and

* In this figure (Plate 7, fig. 6) the germ *d.* is seen separating the exterior scales *c.* which were originally the lobes. It appears to consist of the rudiments of four leaves, which are not, however, the true leaves; but those intermediate between the lobular scales and them, the true leaves being yet latent. The pith of the new branch originates from *a.*: the pale space between this and *b.*, the bark of the embryon branch, is alburnous matter: *e.* is the eschar, formed by the fall of the leaf in autumn, with the spiral vessels which supplied the leaf, now obstructed; *f.* the rudiment of a spiral vessel belonging to the scale *c.*; *g.* the bark of the portion of the shoot above the bud; *h.* the alburnum; *i.* the medullary sheath; *k.* the medulla.

whence, passing up, they distribute bundles to each of the leaves, which appear now completely organized, although extremely small and compressed within the scales of the bud. As the season advances, the bud lengthens; and at the moment of its opening, the young branch is seen stretching forwards clothed with its leaves, which gradually unfolding themselves, display in their axillæ the rudiments of future buds, destined to run the course which has just been described; and become in their turn the parents of another series.

If the young branch be now dissected, it is found to possess exactly the same structure as the stem in the early stage of its growth; that is, to consist of a central pith turgid with fluid, surrounded by the medullary sheath, around which the spiral vessels appear in distinct longitudinal bundles; and beyond them a layer of semiorganized alburnum, bounded by the liber: the vascular fasces of the bark are embedded in the cellular integument, and the whole enclosed by the epidermis, which at this period is generally covered with excretory glands or some kind of pubescence. But after the leaves have expanded and performed their functions for some time, if the branch be again examined, by carrying a longitudinal section into the stem, we perceive its alburnum, now fully organized and continuous

with the new layer in the stem, deposited over that of the former year, which has already become wood: and, as the branch increases annually by new layers, in the same manner as the stem, a similar section made at any subsequent period displays its connexion with the stem, forming a cone, the apex of which touches the medullary sheath of the stem, and the base its surface whence the branch projects. This conical




appearance is rendered more evident by the marginal cut; in which *a.* represents a stem five years old; and *b.* a branch three years old projecting from it. At the points of union (*c. c.*) a kind of raphe is formed above and below the branch owing to the descending alburnous matter of the branch meeting that of the stem.

Such are the appearances which mark the origin of the branch and its connexion with the trunk in the Lilac; and the same, with some modifications, are perceptible in all ligneous dicotyledons. The principal of these modifications is seen in those ligneous stems, the pith of which is interrupted at the points where the buds are formed, as for example in that of the Vine. In it a process from the medullary sheath extending di-

rectly across the ligneous cylinder of the stem, forms an apparently solid diaphragm ; and swelling externally affords a base *a.* (see marginal cut) on which the bud, and consequently the new branch, are seated. This appearance was erroneously supposed by Grew * to be occasioned by the shooting of the branch across the pith; but, it is obviously a process of the medullary sheath; for, when placed under the microscope, it displays the same structure; and the cells of which it is composed are crowded with small granules, as is generally the case in those of the medullary sheath. The colour, which is green like the medullary sheath, distinguishes it from the pith, which is of a fawn colour in the vine. It is not always, however, thrown completely across the pith; for, when neither a bud nor a tendril rises from the opposite side of the stem, it never stretches entirely across, but leaves a free communication between the pith above and below it, at least one third of the circumference of the ligneous cylinder. The plans in the margin illustrate, more clearly, this fact: thus, where the tendril is



* *Anatomy of Plants*, t. 19.

given off, as at *a.* the diaphragm is complete; but at *b.* (p. 390), where there is a bud only, it is incomplete; and this is farther displayed at *c.* in a transverse section of the shoot.

We are now prepared to consider the physiology of the parts that have been just demonstrated. We have seen that the rudiment of the bud is perceptible, in the axilla of the leaf, on the young branch at the moment of its protrusion from the bud in early spring; and that at this period, at least, it is an isolated body, distinct, as Gærtner has correctly asserted, from the proper and permanent members of the plant *. The question thence occurs,—When and how are buds formed? Du Hamel supposed that they originate in what he terms preorganized germs, which are deposited by the proper juice in its descent from the leaves, and pervade every part of the plant †: but, although it is impossible to demonstrate the fallacy of this opinion; yet, if it can be shown that buds, on whatever part of a stem or branch they are found, or at whatever period of the growth of these members they appear, can be traced to their origin in the first year's growth of

* *De Fructibus.* Introd.

† *Phys. des Arbres,* tom. i.

the part on which they appear, it will be at least rendered improbable. To effect this, we have only to saw out a portion of any trunk or branch on which a young bud appears; and carrying our incision down to the pith, and by carefully slicing the portion horizontally, or in a right angle to the surface of the stem, till we divide the bud to its centre, we shall find a white line extending from it, through every concentric layer of the wood, till it touches the medullary sheath. Thus, in the wedge, represented in Plate 7, fig. 5, cut from the trunk of a Lilac twenty years old, we can trace the buds *a. b.* to their very point, which terminates at the pith of the plant; and the same is the case with the three buds *a. b. c.* of fig. 6, in the same plate: for, although *a.* appears to spring from the surface of the third circle of the stem when examined with the naked eye, yet, under the microscope (see fig. 7), it is seen to stretch to the medullary sheath, in conjunction with its fellows. It is argued, however, that if an Oak, or any old tree, be cut down in winter, leaving the root in the ground and a foot or two of the trunk, we shall find on the margin of the stump multitudes of buds protruding in the following spring. I admit the fact; but deny the conclusion inferred from it, that these buds originate on the surface where they appear; for, if they do not all push out on the same plane, which is

the fact, I have no doubt that each could be traced to the centre of the trunk; as I have found to be the case in the Willow and some other soft-wooded trees, which after being cut down, have displayed the same appearances as the Oak; and although I have had no opportunity of examining the Oak, yet, there is no reason for supposing it an exception. If buds, therefore, be pre-organized germs, they can be deposited only in the first year's growth of the stem or branch, the admission of which would defeat the object of Du Hamel's hypothesis.

These facts, also, render less tenable the doctrine of Mr. Knight, that buds proceed from the alburnous vessels, which he supposes have the power to generate central vessels *: for, if this were the case, buds could be traced no deeper than the alburnum of the season in which they appear. Neither is the opinion strengthened by the fact, that if buds be destroyed in early spring, others appear; for, in this case, either the buds are such as have not been cut or rubbed off at a depth sufficient to extinguish their vitality, and prevent them from shooting forth again laterally, or by destroying the already protruded buds, those that remain latent, two or more germs being often present in the same vital stream, if I

* *Phil. Transactions*, 1805.

may be allowed the expression (see Plate 7, fig. 7, *a. b. c.*); receive a new impulse, sufficient to call into action their dormant powers, and enable them to protrude and evolve their leaves, in the same season; which, had the other buds been left, might not have happened for many years to come.

This fact is practically known to nurserymen and gardeners, who, without any theory, but guided by their experience, act upon it in order to obtain a clean Cherry tree stem. No tree is so apt to throw out adventitious buds as the Cherry tree; but as this would deform and injure the plant, the nurserymen cut them off close to the bark. A second crop of shoots, very soon afterwards, makes its appearance, which is also taken away by the knife, after which no other appears; and, if the stem be now cut through under the existing branches, it ceases to grow. I am of opinion that the same circumstance would take place in forest trees, were all the lateral buds of the leading shoot annually rubbed off, so as to bring forward every latent germ; and, by destroying the successive crops of buds as they are evolved, a clean stem perfectly free from knots might always be insured. That the buds, when they first protrude, receive their nourishment from the descending proper juice, is extremely probable; but this would also be the case

did they arise from the pre-organized germs of Du Hamel. If this reasoning be correct, the first division of our question is already answered; and we may conclude that all stem buds originate when the young stem is evolved from the seed, and all branch buds at the time that the young branch is formed in the axilla of the leaf. They are not, however, all protruded during the succulent state of the stem and branch, but many remain latent, performing so much of their functions only as is requisite to organize to their proper structure a certain portion of each successive annual layer of wood, and carry them forward in the embryon state; until circumstances occur favourable to the completion of their organization and protrusion on the surface of the stem; or until some accident destroys them*.

If buds be not pre-organized germs, nor formed from the descending proper juice; how then do they originate? I reply, in vital points *(puncta vitalia)* generated, in the first period of the growth of the stem and the branch, in the axillæ of the leaves: or that they are, to use the language of Darwin, distinct individuals, the lateral or viviparous progeny of the parent upon

* In Plate 7, fig. 8, *a.* represents a bud which has been destroyed in the fourth year of the growth of the stem; and over which the subsequent layers of wood have formed.

whose surface they appear *. The individuality of buds must have been suspected as early as the discovery of the art of budding †; and it is fully proved by the dissection of plants, as we have seen in the demonstrations before us. The vital energy, however, which commences the process of organization in the bud, is not necessarily confined to the germ, nor distinct from that which maintains the growth of the entire plant; but it is so connected with organization, that when this has proceeded a certain length, the bud may be removed from the parent and attached to another, where it will become a branch the same as if it had not been removed; or, with proper care, it may be made to grow in the earth, and become an entire plant, with all the properties and physiognomical characters of the parent.

* Malpighi taught that the gems are formed in the pith, which he regarded as a viscus intended for this purpose and the elaboration of the sap. Thummig, a German author who wrote in the 18th century, imagined that the medulla contains the rudiments of the gems: Darwin suspected that the embryons of the buds are secreted from the "vegetable blood" at the footstalk of each leaf; while Mr. Knight supposed that they are generated by the alburnous vessels from the descending proper juice.

† Budding is that operation in gardening, by which a bud taken from one tree is transferred to another, with which it unites and becomes a branch. It is founded on the fact, that the bud, which is a branch in embryo, is a distinct individual.

The ingenious Bradley supposed that a bud takes root in the body of a tree in the same manner as a seed takes root in the earth *; an idea which evidently suggested Darwin's theory of the individuality of buds, and the augmentation of the diameter of the trunk and branches by the extension of their radicles, as has been already noticed; and which has since been illustrated, and given to the world as his own, by a celebrated French phytologist, M. Aubert Du Petit-Thouars †. But, although a bud will send out roots and grow if planted in the ground, the analogy does not apply to the bud attached to the original parent, nor even to that which is budded.

Before organization commences in the germ, it is, as we have seen, an insulated speck, covered by the epidermis only, and connected with the other parts of the stem or branch, in which it is seated, merely by cellular matter. The effect of the organic power on it is the addition of new matter, and the consequent evolution of its parts; till gradually extending in the direction of its axis, it unites with and becomes a permanent part

* *Discourses on the Growth of Plants*, 1727, p. 56.

† This is rendered evident by comparing the theory delivered in his work, entitled *Essais sur la Végétation considérée dans le Développement des Bourgeons;* which was published in 1809, with that in the *Phytologia* of Darwin, which appeared in 1800.

of the plant. The quantity of amylaceous granules contained in the cells surrounding the germ, renders it probable that it receives its first nourishment from this source; and it is not less probable that the lobes which surround it, perform for it a similar function to that of the cotyledons, or seed-lobes, as connected with the embryon enclosed within them, or that of the leaves in reference to the stem and branch; which we shall afterwards prove to be analogous to that of the lungs in animals. But it is, also, probable that the leaf above the bud supplies part of the pabulum which is elaborated into the new branch; for, until its own leaves are expanded in spring, and capable of producing that change on the sap which converts it into proper juice, no alburnous matter can be formed by them. The descending juice, however, from the leaf above the germ, is not conveyed to it by any vascular communication, but deposited in the cellular mass or placenta, if it may be so termed, on which it is seated; and by which alone it is connected with the medullary sheath of the parent shoot. In the germ or vital speck, thus situated and supplied with nutriment, the organization of the branch commences as from a centre. It is not probable that we shall, ever, be able to trace every minute change, which occurs from this period until the first rudiment of the new branch is perspicuous, even by the aid of the best microscopes;

but the first part that can be distinctly recognised is the pith, which, in a longitudinal section of the green twig of the Lilac, made three weeks after its protrusion from the bud, and the appearance of the gem on its surface, resembles a more opaque spot of a greenish hue; with lines running in a direction from the centre of the parent branch towards the apex of the gem. These are the first traces of the spiral vessels of the future branch (see Plate 7, fig. 9, *a*.). The cellular matter, in the part of the bud above the vital speck, which now appears as at *c*. displays also at this period a more regular form, and indications of its separation into scales are already perceptible at *b*.; but the whole bud is still a completely insulated body. As the organization proceeds, new scales are seen separating from the mass of parenchyma, the medulla enlarges in every direction, and in autumn the whole presents a pyramidal appearance; in which state the bud remains nearly stationary until the ensuing spring.

As the cessation of the vegetative power in winter increases in a great degree the excitability of plants which outlive its severity, the genial influence of spring is very early visible on their buds, in which the whole vital energy of trees and shrubs may be supposed at this period to reside; and it is only by the visible change which rapidly occurs in them, that we can pronounce upon the

life of the entire plant. If a longitudinal section of a twig be examined at this time, although the pith be, generally speaking, a dry spongy mass, yet, a little above and below the parts where the buds appear, it is succulent and green. This can be explained only by supposing that the increased vital energy of the buds is extended around them to a certain degree, maintaining the lateral communication through the pores of the cells, while these have now become impervious in other parts; and by this effect a sufficient supply of nutriment is provided for the bud, which, enlarging in every direction as the spring advances, at length opens its scales and pushes forwards, into the light and air, the young branch with its leaves and flowers. On examining now the connexion of the shoot with the stem or branch, we find it no longer an isolated individual, but seated closely upon the medullary sheath of the parent; and the alburnous matter which is deposited between its bark and pith, continuous with that thrown out from the liber of the old bark, already giving origin to a ligneous layer, that forms both a connecting vinculum between the tree and the new branch, and a support to the latter in its projecting position.

I suspect that Hill confined his examination of buds to the autumn, and before they were ready to open in spring; and thence he was led to adopt the opinion that the branch originates

from the vessels of the medullary sheath, which, as I have already remarked, he termed the corona, holding it to be the most important part of the plant *. The difficulty of explaining the appearance of adventitious buds on such a supposition, led to the rejection of his theory; and I am surprised to find that a late ingenious writer † supports the fallacy of it by this remark: " it is notorious, that trees in which not only this first circle, but almost every other circle of vessels has perished, produce leaves and shoots from the trunk where the bark is entire, as this author himself admits, p. 44 of his work:" for, independent of the absurdity of imagining that the life of the tree could be supported at all, if every circle of vessels had perished, the objection displays an unaccountable neglect of investigation.

I trust enough has been demonstrated, in the dissections laid before you, to establish the fallacy of Hill's theory; but on different grounds from those taken up by the author above quoted; and I have now only to explain how the appearance of adventitious buds on hollow trees does not militate, in any degree, against the theory I have advanced. In doing so, I must recur to my position, that every bud originates with the branch or stem on

* *Hill on the Construction of Timber*, p. 21.

† Mr. Ellis: see the article *Vegetable Anatomy*, in the *Supplement to the 4th and 5th editions of the Encyclopædia Britannica*, vol. i. Part 2. p. 335.

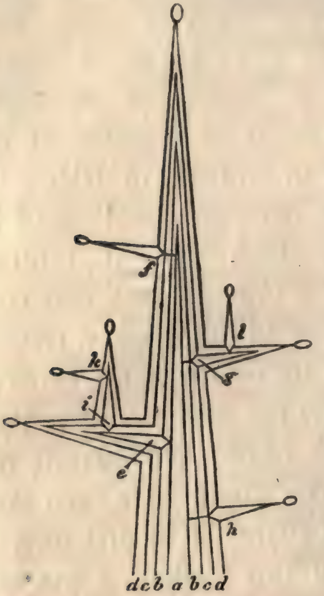
which it appears, but is not always evolved in the season in which it is generated. When it appears at any future time, therefore, although it is, as I have demonstrated, traceable from the medullary sheath to the surface on which it appears, yet, the maintaining a communication with that sheath has long ceased to be requisite, either for its preservation or its nourishment; and, consequently, it is not affected by the destruction of that part, or of the circles of wood intermediate to it and the bark. The pale streams of parenchyma traversing these circles, only mark the track in which the vital speck or germ has advanced to the surface of each annual zone, where it was ready to be developed, had circumstances been favourable for that event; but this streak of parenchyma is altogether useless as far as regards the gem, except in the zone on the surface of which it is seated, and with the life of which its vitality is, indeed, intimately connected. Destroy this zone, and the latent germ becomes extinct; increase its vital energy by any means, as, for example, by lopping off a branch, and the germ is evolved into a perfect bud and branch; but leave the parts as they are, and the vital speck advances to the surface of the next zone which is formed over the present, and so on progressively, until it is ultimately evolved, or perishes with the destruction of the tree. The bud, therefore, which appears on the surface of a hol-

low tree, is still to be regarded as having originated in the first year of the life of that trunk, however old it may be: and its progress may be traced through the shell of wood which still remains free from decay.

In general the latent germ passes in a straight line through each concentric layer of wood; but when a branch, which is given off at an acute angle, coalesces with the trunk, its direction is changed to a curve, so as to continue it in the wood of the stem or branch in which it originated. Thus in the horizontal section of a Willow, now before us, which was cut a little below the bifurcation of a branch, that had coalesced with the trunk, we find the bud *a.* traceable in a direct line from the centre of the trunk; but *b.* as soon as it enters the zone *c.* where the coalescence occurs, turns aside, and instead of being protruded at *f.* which would have been the case had it continued its course in its first direction, it appears at *b.* In this section, *d.* marks

the last independent ligneous zone of the branch, and *e.* that of the trunk: but it must be remarked that the other zones, common to both, are the result of alburnous matter furnished by each in particular.

A very clear idea of the origin and connexion of branches may be obtained by the aid of a diagram, similar to one which was employed by Du Hamel to illustrate the opinion he entertained, although that was directly opposite to the theory I have advanced. Let us imagine the figure in the margin to be a tree four years old; the cone *a.* representing the first year's growth, *b. b.* the second, *c. c.* the third, and *d. d.* the fourth. The buds furnishing the branches *e. f. g. h.* are all generated on the surface of *a.* in the spring of the first year; but in that year *e* only sprouts into a branch; on the surface of which is generated *i.*, which in its turn generates *k.* In this series, each branch has sprung in regular succession from that of the former year; the age of the branch being marked by the num-



ber of ligneous layers: thus *k.* which is one year old, is covered with one ligneous layer; *i.* with two, and *e.* with three; while the original trunk has four, which give the age of the germ, whence *e.* originated. But *g.* has two layers only, and *f. h.* no more than one, although shooting from the same surface as *e.* which is thus explained. The branch *g.* sprung from an adventitious bud, which protruded in the second year of the growth of the stem; and, therefore, although the germ whence it originated is as old as that of *e.* yet it is covered with two ligneous layers only; and the branch *l.* which it has produced in regular succession has but one, or is no older than *k.* the third in succession on *e.* In the same manner the branches *f.* and *h.* which have also sprung from adventitious buds, are of the same age as *k.* although their germs were generated on *a.* and are consequently coeval with the first development of the trunk.

Such are the observations which I have thought necessary to be laid before you to illustrate the origin of branches and their connexion with the trunk; from which the following conclusions may be drawn: 1. That every branch originates in a bud or germ. 2. That every bud or germ is a distinct isolated individual, the lateral progeny of the plant, and generated at the first development of the stem or branch on which it appears; but, after some time, increasing by

its own organic powers it forms a branch, and becomes a part of the tree or shrub which has produced it. 3. That every adventitious bud, or bud appearing at any after period, originates in a germ generated at the development of the stem or branch on which it appears, although it has hitherto remained latent. 4. That every latent germ is annually carried forward, in a horizontal direction, through every concentric zone of wood, intermediate to the medulla and the surface on which it will sprout into a branch; leaving behind it a substance of a peculiar structure, somewhat resembling a white cord penetrating the ligneous zones, by which its progress can be traced. 5. That every branch when fully developed, displays the same structure as the stem.

In examining the structure of the ROOT in ligneous Dycotyledons, it will be useful to follow the division of this organ into *caudex*, *radicles*, and *fibrils*, which I adopted in describing the external characters of roots in general; and to examine each part separately, beginning with the caudex.

*a.* The *Caudex*.—Taking the Horse Chesnut still as the subject of our examination, we find that the caudex of the root consists of the same parts as are found in the trunk of the tree, arranged in the same relative order, and that each

part, when placed under the microscope, displays nearly the same structure as the corresponding part above ground. Thus in the bark we find the *cuticle* with its horizontal vessels terminating in the parenchyma; the *cellular integument* consisting of regular hexagonal cells; and the *liber* displaying its reticular meshes. The cells, however, are larger than those of the caulinar bark, and are filled with a fawn-coloured instead of a green fluid. The circle of *alburnum* and of *wood* differ in nothing from those of the stem; except that the vessels, which are also cribriform, and the cells of the divergent layers contain numerous transparent granular bodies, which are likewise found crowding the cells of the medullary sheath and those of the pith. I have not been able to discover any spiral vessels in the *medullary sheath* of the root-caudex, even in the youngest trees; in which particular, therefore, the root differs from the stem. The *pith*, which is larger than that of the stem, consists of hexagonal cells, turgid with fluid, and so crowded with the granular bodies already described, as to obscure their hexagonal structure, which, however, can be distinctly observed in a very thin section.

Such is the root-caudex of the Horse Chesnut in the second or third year of its growth; and it may be taken as an example of the structure of this

part in the majority of ligneous dicotyledons. While it remains entire, the young tree may be regarded as composed of two similar cones united at their bases; the one rising vertically, or nearly so, above the surface of the soil, and the other, which forms the root, taking the opposite direction and penetrating the earth by constant additions made to its apex. The place of their union is distinguished externally by an impression as if a cord had been tied very tightly round the stem; and is that part which the French term *collet*, in the first evolution of the plant in the germinating seed. If the apex be destroyed, it ceases to elongate in the direction of its axis, and shoots out lateral branches; but these are given off at various other parts also during its extension, and form divisions resembling those of the trunk and the branches above ground.

*b.* The Radicles. The medulla disappears in the radicles, whether they be given off from the caudex or a branch; but something like the medullary sheath is still present. The radicle, therefore, consists of a spongy centre, resembling the medullary sheath devoid of spiral vessels, surrounded by a circle of ligneous vessels, which are either cribriform as in the Horse Chesnut, or annular as in the Vine (the character of the vessels in the radicle being always the same as that of those in the stem and branches); and a bark, which is

much thicker than that of any part above the soil. The vessels are so arranged as to give a radiated appearance to a transverse section, and I have been able to trace the presence of divergent rays; but I am doubtful whether these are always present in the smaller radicles. In the Vine we sometimes find the bark running inwards, and dividing the vessels into distinct wedge-like bundles (see Plate 7, fig. 11. *); and this may be the case, also, in other radicles, to supply the place of other divergent layers.

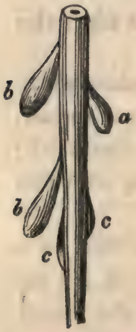
The radicles given off from the caudex appear to proceed from the medullary sheath and the first ligneous layer; and, like the branches above ground, originate in the first year's growth of each additional length of the root, for they can be traced to the medullary sheath in the thickest caudex. When, however, they are given off from a stem or a branch which has been laid down in the ground, they originate in the alburnum of that season (see Plate 6, fig. 9 †); and this is also the

* In this figure, *a.* marks the pith in the slice of a shoot which had been laid down and had rooted; *b.* the first year's wood; *c.* that of the present year whence the radicle *e.* has shot forth; and *d.* the bark, the cuticle of which is seen uniting with that of the radicle.

† In this figure, which displays the transverse slice of a Vine radicle magnified 750 times, *a.* marks the cuticle and the parenchyma of the bark; *b.* the divided orifices of the proper vessels of the bark; and *c.* those of the ligneous vessels.

case in those radicles which shoot out above the caudex when the soil is heaped up around the stem. From whatever part the radicles proceed, they are always given off in such a direction as to form a right angle with the surface of the part, which would not be the case did they descend from the stem buds, as Dr. Darwin and M. A. Du Petit-Thouars assert; for, were their opinions correct, the radicles would be given off from the caudex in the same manner as a few threads are separated from a skein of thread. The radicle, on the contrary, receives vessels from the layer of the caudex on which it originates, from both above and below the point whence it shoots. I have not been able to trace the origin of the radicle; but it is probable that every layer of alburnum is capable of producing radicles; for it is only necessary to apply moist earth round any part of a stem or branch to make them protrude.

c. The *Fibrils* *, soon after they are visible on




the radicles of the Horse Chesnut, are minute, ovate, semitransparent bodies (see *a.* marginal cut, which represents a fibril considerably larger than in nature), and, when placed under the microscope, appear to consist of a spongy mass of cellular matter, enclosed in a thin transparent pellicle,

* These are the *capillamenta* of Malphigi, *Anat. Plants*, p. 145.

perforated with absorbing pores: such is their earliest character in every dicotyledonous root I have examined. At this period they are productions of the bark only of the radicle; but a few ligneous vessels soon shoot into their centre, and they begin to lengthen (see Plate 8, fig. A. B*); always, however, retaining a clubbed appearance at the apex (see *b. b.* marginal cut). They shrivel up in a few seconds after the root is taken out of the earth, and then appear as represented at *c. c.* (marginal cut); but so great are their absorbent powers, that, when perfectly dry, if thrown into water, they expand again in a few seconds to their original size. The minuteness of these pores renders it impossible, even by the aid of the most powerful glasses, to obtain a knowledge of their structure; and although the fibril shrivels so quickly, yet the smallness of the parts prevents us from determining whether this shrivelling be the consequence of exhalation, or of the fluid being carried forwards into the radicle. Whatever may be the structure of these pores, they are evidently

* Fig. 1 A. represents, greatly magnified, the entire fibril soon after it begins to lengthen; the dark shade *a.* in the centre being produced by the ligneous vessels, which are more opaque than the cellular matter; *b.* is the real size of the fibril. Fig. 1, B. is a transverse section of the same fibril; *a.* the vessels, *b. c.* the cellular matter filled with transparent granules, which are much more numerous in the exterior circle *b.*; *d.* the real size of the section.

the absorbent mouths of the root, and must either possess a valvular apparatus, or a power of contracting strongly, so as to enable them to retain the fluid they imbibe, until it is taken up by the ligneous vessels. From their forming on the radicles and their divisions, and seldom or never on the caudex, they are placed at a distance from the trunk of the tree; and consequently seeds and small plants thrive better close to trees, than at a little distance, the earth being less exhausted in the vicinity of the larger roots than where the radicles spread.

I have already stated (p. 129) the opinion of Du Hamel and some other phytologists, regarding the annual death and reproduction of the fibrils; and the objections to it urged by Mr. Knight. My own observations induce me to believe that fibrils are annual productions in all deciduous trees and shrubs, although they are perennial in evergreens. Were I called upon to suggest a reason for this distinction, I would say, that, as the fibrils do not appear until the leaves begin to expand, they are produced for the purpose of maintaining a due balance between the absorption and the exhalation of the plant, and to secure a supply of nutriment in proportion to the demand, which must always depend on the energy of the leaves in which it is converted into the proper juice of the plant; and, therefore, when the

leaves decay and fall in autumn, the function of the fibrils being no longer required, they also decay and separate from the radicles; but in evergreen shrubs, the office of the leaves being permanent, the new set always appearing before the old set falls, the continued presence of the fibrils becomes also requisite.

Such is the root of ligneous dicotyledons. Its similitude both in structure and functions to the portion of the tree above ground is very obvious, the caudex resembling the stem, the radicles the branches, and the fibrils the leaves; and hence trees have been inverted and yet have lived; the buried stem and branches being converted into roots, whilst the roots elevated into the air and light have assumed the characters and performed all the functions of the organs, the place of which they now supply.

B. HERBACEOUS DICOTYLEDONOUS STEMS are so much diversified in structure, particularly as far as relates to the arrangement of the parts, that it is impossible to form as accurate an idea of their anatomy from the examination of one or two specimens, as we are enabled to do of that of the stems of dicotyledons. To obviate, however, in some degree, this objection, I shall divide them into two classes, comprehending under the first A. *those which have no central cavity, or are entire,* and

under the second, B. *those which are hollow;* so that by again subdividing these, I shall be able to convey to you some general ideas of the prominent characters which constitute the diversities.

A. The *entire stem* has no conspicuous internal cavity, but the whole of that space which is filled with the medulla in solid ligneous dicotyledons, is made up of cellular matter turgid with fluid. The stem, indeed, consists chiefly of similar cellular texture, with detached bundles of vessels regularly arranged through it, and the whole enclosed by a bark. As the difference in point of structure in this class depends on the arrangement of the vascular bundles, it may be divided into two genera; the *first, a.* comprehending all those *herbaceous dicotyledonous stems in which the disposition of the vascular bundles approaches to that characterizing monocotyledonous stems;* and the second *b. those in which it resembles, in some degree, the concentric circles of ligneous dicotyledons:* each of these genera necessarily including many species and varieties.

*a.* To illustrate the first of the genera of stems just defined, I have selected the stem of the White Bryony, Bryonia *alba,* because it is a plant very readily procured.

If we examine with the naked eye a thin transverse slice of the stem of Bryony, placed on a dark surface, we perceive that it consists of a

pale green opaque bark, enclosing a transparent parenchyma studded with fourteen opaque ovate spots of the same colour as the bark, and having a white dot in the centre of each spot (see Plate 8, fig. 2, A). Placing the same slice under a microscope of a moderate power, we find that the transparent portion is formed of hexagonal cells of different sizes; and each spot consists of the divided orifices of two clusters of oblong cells and entire vessels, surrounding one large and several small sap vessels. The bark appears to consist of a cuticle and three distinct cellular bands, the central one of which is filled with a green fluid, and may be regarded as equivalent to the green cellular integument in ligneous dicotyledons; except that it penetrates the outer band to the cuticle at nearly equal distances (Plate 8, fig. 2, B). If we take a small portion of this section, and also of a longitudinal slice of the stem, and examine them under the highest power of the microscope, we shall find the real structure of this kind of stem to be as follows. The cuticle is irregularly reticulate and streaked with green cellular lozenge-shaped spots (Plate 8, fig. 3, *a. a.*), which are the processes of the middle band of the bark; the outer cortical band, or that immediately within the cuticle, consists of narrow tubular cells (see *a. a.* fig. 4, A and B. Plate 8); the second of shorter and wider cells (*b. b.*), filled with the green secretion already noticed, and penetrating to the

cuticle at *l. l. l. l.* (Fig. 4, A.), so as to give the stem its striated aspect; and the third band (*c. c.*) is composed of entire vessels. Although we may regard the part just described as analogous in some respects to the cortex in ligneous stems, yet in others it differs materially from that organ; and it can neither be separated entire from the parts beneath, nor can the bands be detached from each other without destroying the organization. Immediately within the vascular band of the cortex we find the cellular mass *d. d. d. d.* composed of cells which appear more or less regular hexagons in the transverse section (Fig. 4, A); but in the longitudinal (B) their length is seen to be more than twice the sum of their diameter. They are larger and more regular in the centre of the stem; and the hexagonal shape is sometimes lost, in order to accommodate them to the forms of the vascular fasciculi. The cells are filled with a thin mucilaginous fluid, which is more viscid in the vicinity of the vascular band of the cortex and the vascular fasciculi; but, as the season advances, it almost disappears in the central cells, which then assume the character of the pith in dicotyledons. All the cells are perforated. The vascular fasciculi contain from seven to ten central vessels; one of which (*f. f.*) is very large, and the others (*g. g. h. h.*) smaller in a regular ratio as they are distant from it, or towards

the centre of the stem: these are surrounded by a double cluster of entire vessels, which in the transverse section appear like small hexagonal cells (Fig. 4, A. *e. i.*); but in the longitudinal (B. *e. i.*) they display their proper character, although it is not improbable they are divided, at certain distances, by diaphragms which the transparency of their coats conceals. The central vessels are not all of the same structure, the larger being annular, with oblong pores (Fig. 5, *a.*); the next size spiral, with the fillet either punctured or studded with glands (Fig. 5, *b.*), for I have not been able to satisfy myself on this point; and the smallest (Fig. 5, *c.*) of the same structure as those vessels, which I have already described as existing in the stem of Tradescantia and of some other herbaceous monocotyledons. These consist of isolated rings, separated from each other by a space equal to their own diameter, which are apparently intended as a frame-work to keep extended a simple membranous tube in which they are enclosed (Fig. 5, *c.*).

Mr. Kieser is the only phytologist who has published any description of the last-mentioned form of vessel; but he regards it merely as the substratum or origin of the annular punctuated spiral*; and, had I seen it in the stem under

* *Mém. sur l'Organisation des Plantes*, Haerlem, 1814.

consideration only, I should have adopted his opinion, as it is the innermost and apparently the least perfect of the series in each fasciculus: but having seen it, in a more perfect form, in the Tradescantia; and not being able to conceive why those distinct rings should exist only to be transmuted into punctuated spirals, I am inclined to consider it a distinct vessel. It is true, as Kieser has observed, that the membranous vessel, or intervening membrane as he terms it, is punctuated; but he appears to have overlooked the fact, that the rings are retained in their places by minute acicular bodies, which I have separated from the vessels in Tradescantia, although I have not succeeded in doing so from those in the Bryony. No such bodies are seen attached to the real annular vessel; and in the spiral vessel (Plate 8, fig. 5, *b.*), which is the intermediate of the large annular vessel and the ringed membranous vessel in the Bryony, the flattened fibre or fillet forming the spirals is itself punctuated. Notwithstanding, therefore, the apparent probability and simplicity of Kieser's theory of the transformation of the ringed membranous vessel into the punctuated spiral; and this into the annular, in the description of stem now under consideration; I am still of opinion that the central vessels, in the vascular fasciculi in the stem of Bryony and of similar plants, are of

three distinct kinds, as I have represented them (Fig. 5, plate 8), viz. the annular, the punctuated spiral, and the ringed membranous.

Such is the general structure of those herbaceous dicotyledonous stems, which approximate in some of their characters to monocotyledonous stems, particularly in the arrangement of the vascular fasciculi through the parenchyma. But, in regarding the Bryony as a good specimen of the structure of this our first division of herbaceous dicotyledonous stems, we must bear in mind that the division admits of many modifications. In all, however, the fasciculi are distinct, as in the stems of monocotyledons; the chief feature that distinguishes them from monocotyledonous stems, being the presence of a decided cortex, more or less approaching the characters of that which is always present in ligneous dicotyledons; while the stem of the monocotyledon is a fascis of vascular fasciculi, interspersed with cellular matter and covered only by a simple cuticle.

*b.* The structure of the *entire herbaceous stem, in which the arrangement of the parts approaches to that in trees and shrubs*, is well illustrated in the Madder, Rubia *tinctorum*. In a transverse slice of the stem of this plant, which is hexangular, we find the following parts: 1. a cortex *a.* (Plate 8, fig. 6) easily separable from the parts beneath it; 2. a vascular layer, *b.* resembling in its con-

tinuity the first concentric woody circle in a ligneous stem, and 3. a cellular pulp, *c.* which gradually loses its aqueous contents, and assumes the characters of a real pith. By the aid of the microscope, we find that the cuticle consists of a thin, transparent, cribriform membrane; and encloses a cellular cortex (Plate 8, fig. 6, B.), the second layer of the cells of which *a.* is filled with a green coloured fluid, which extends over four or five layers at each angle, and is the source of the colour of the stem. Beneath this green secretion the cells contain a pale yellow fluid, which gradually deepens towards the interior of the cortex, where we find its source, the proper juice, filling a range of narrow oblong cells *b.* which are situated close to *c.* the layer of returning vessels. In these the proper juice is much paler than in the adjoining cells, which is probably owing to its dilution, in consequence of the greater fluidity which is necessary for permitting its motion in the vessels, through the cribriform coats of which it passes into the adjoining cells, where it is inspissated by rest, slowly spreading its colour outwards by the lateral communication of the cells. In *d.* which may be termed the woody layer, and which consists of the large or sap vessels embedded in a green pulp, we find the vessels arranged like wedges pointing inwards, separated by cellular septa, and thus forming a continuous band enclosing the cellular pa-

renchyma *e.*, and which is altogether composed of hexagonal cells, that become larger and more regular as they approach the centre; and supply the place of the pith. The green secretion in the pulp of the woody layer slightly tinges the fluid in the cells of the pith to some distance from the circumference; but, the colour being more and more diluted, the central cells are completely colourless. The sap vessels are spiral, each being composed of three distinct filaments. The proper or returning vessels are cribriform and extremely delicate.

As in the former division of this description of herbaceous stems, there are many modifications of structure, so, in some instances, in this division, it approaches more closely to, and in others recedes more widely from, the characters of that of trees. Thus, in the stem of Endive, Chicorium *Endivia*, which Malpighi has described *, the vessels near the circumference are disposed in lines directed towards the centre, and are separated by small septa of compressed cellular substance; but the interior, which are also the larger, extend in rays a considerable way through the pith. In the stem of Lettuce, Lactuca *sativa*, which may be regarded as the intermediate of the two divisions already noticed, the sap vessels being in distinct fasciculi like those of the first, but arranged in

* *Anatomia Plantarum*, p. 25.

one circle only round a pith, like those of the second, I find that the fasciculi resemble those in the Bryony, with the sap vessels, however, arranged in distinct divergent rays in each fasciculus. The divergence, also, being on that circumference of each fasciculus which is towards the centre of the stem, and all the rays pointing more or less to that centre, they are necessarily of very different lengths: the longest rays generally containing from six to ten vessels, whilst the number in the shortest seldom exceeds two or three. Between each ray we find the same condensed cellular septa which Malpighi has described as existing in the Endive. The sap vessels are all punctuated spirals; but I have not been able to ascertain satisfactorily the structure of the returning vessels, their delicacy, transparency, and the milky nature of the juice they convey rendering it impossible to make out their characters distinctly, even under a microscope of the highest power. I have some reasons for believing that they are membranous and cribriform.

In concluding the view I have taken of this division of herbaceous stems, it is necessary to point out an exception to the general rule, that all ligneous stems are necessarily perennials, and all the herbaceous either annuals or biennials. In the Thorn Apple, Datura *stramonium*, which is an annual, generally described as herbaceous, and which contains a large proportion of a very

spongy, lax, pith, the stem, when examined under the microscope, displays every character of the real ligneous stem; resembling particularly that of the Elder, except that the cells of the divergent rays in the Thorn Apple are nearly square, whereas those of the Elder are oblong. The stem of Thorn Apple is in fact a soft ligneous stem; and, consequently, has been hitherto incorrectly classed as herbaceous. The softness of the stem is no argument against this decision, and only demonstrates the great diversity, with respect to induration, which wood displays.

B. *Hollow herbaceous stems* may, also, be described under two subdivisions; *a. the fistulous or unpartitioned*, and *b. the partitioned.*

*a.* In internal structure there is little to distinguish the *fistulous* or *unpartitioned* hollow stems from those of the last división, except the deficiency of the pulp or pith which constitutes the hollow; some of them, in every other respect, resembling closely the Bryony, or those of the first subdivision; and others those of the second. With regard to the cavity in the centre of the stem, in some it is apparently the consequence of an original deficiency of cellular matter; for that which exists has evidently undergone no compression; whilst in others it is evidently compressed, and the hollow seems to be the result

of air introduced into the centre of the stem at a period subsequent to the formation of the pith, which at first fills up the whole of the space within the vascular circle. Whether the air contained in these stems be introduced from without or generated in the stem as a secretion, is still a question in phytology. Examining it eudiometrically, I found that the stem of Cow Parsnep, Heracleum *sphondylium,* contains a little more carbonic acid gas, than atmospherical air, from which it differs in no other respect. But if it be a secretion, the components will probably vary in different stems *.

*b.* The internal structure of the *partitioned* hollow stems is the same as that of the fistulous, except at the knots where the partitions are situated. In selecting the stem of Common Hemlock, Conium *maculatum,* to illustrate this part of their structure, I shall point out to you a variation in the arrangement of the fasciculi of descending vessels, which is peculiar to this plant and a few others of the same natural order of the umbelliferæ.

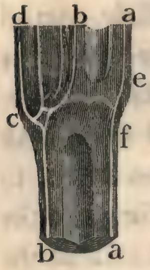
If we place a transverse section of the stem of Hemlock under the microscope, we find the cortex to consist of a cuticle composed of a thin cribriform epidermis, covering two rows of square cells *a.* (Plate 9, fig. 8); and a cellular integument, *c.*, through which the proper vessels descend

* This part of our subject shall be fully discussed in its proper place.

in large flattened fasciculi *b. b.* placed near the cuticle. Immediately beneath the cuticle, round the fasciculi of proper vessels, and bordering the cellular integument interiorly, the cells are irregular, smaller than in the centre, and filled with a green secretion, which gives the green colour to the stem; but the colouring matter forming the blotches or maculæ is deposited in the cells of the cuticle. Within the cortex, the principal bundles of sap vessels, *d. d.* with their accompanying descending vessels, are placed at equal distances round the circle, and stretch inwards, affording in the transverse section a form not unlike the print of the human foot. These alternate with smaller fasciculi, *e.* each of which is accompanied by three clusters of descending vessels; the circumstance in which the peculiarity of this stem consists. The cellular matter is composed of irregular hexagonal cells, turgid with a colourless mucilaginous fluid, which becomes firm and elastic when the part is placed in cold water.

The nature of the septum or partition, which interrupts the cavity of the stem at each knot, in this description of stem, is readily seen in a longitudinal section. By the aid of a common lens, the vascular bundles are easily traced, by their whiteness and opacity. Thus in the marginal figure (see next page) the white line *a.* is a bundle which runs uninterruptedly upwards on

the side of the stem where no leaf is given off;




but *b.* when it arrives at the base of the leaf *c.* divides, and one part *d.* enters the leaf, while the other, curving inwards, continues its course along the stem: it then gives off a bundle a little higher up, which anastomozing with a bundle from *d.* forms part of the fasciculi for supplying the new shoot, originating in the axilla of the leaf. The septum is not a thin plate or diaphragm traversing the hollow of the stem; but a mass of cellular substance, which, in the example before us, occupies the space from *e.* to *f.* and is condensed in the centre where it appears white and opaque. In a thin longitudinal slice examined under the microscope, we find that the cellular matter forming the septum is the same as that of the other parts, except where it is condensed in the centre (Plate 9, fig. 9, *h.* *), at which place the cells assume a horizontal position, as if the cellular texture in the parts above and below terminated at that spot,

* In this figure (which represents a longitudinal section, passing through the smaller vascular fasciculus marked *e.* fig. 8), *a.* is the cellular matter of the cortex; *b.* a bundle of proper vessels separated by a slip of cellular substance from the sap vessels *e.* which are simple spirals, surrounded by a few oblong cells *d.f.*: the cells *g.* which supply the place of the pith, are condensed at *h.* forming the real septum in the hollow partitioned stem.

and the boundary of the one compressed that of the other; each mass exceeding in length the space it is intended to occupy. In the old stem, however, when the pulp which constitutes the pith becomes dry and the cells empty, the diaphragm is condensed to a thin opaque plate.

In both kinds of hollow stems, the sap vessels are spirals, formed of one or two flat, entire or punctured threads; while the proper vessels, as far as I have been able to observe them, are simple, transparent, cribriform tubes. The number of vessels varies in each fasciculus, generally increasing with the growth of the plant, and consequently the same fasciculus consists of a different number of vessels, according as the part in which it is situated is nearer to, or farther from the root. Thus, in a mature stem of the Gourd, M. Kieser, who took the trouble of counting the sap vessels, says the number in each fasciculus, near the top of the stem, seldom exceeds six or seven, but below the second knot it is nineteen, and still greater below the third. In the centre of the stem the number of vessels in each fasciculus is twenty-three, and near to the root twenty-nine, if the stem be examined in autumn. But besides this diversity with respect to number, Kieser asserts that the size and general characters of the vessels vary. At an early period, or near the summit of the plant, he says they are *simple spirals;* lower down they are of a larger size and *annular*

*spirals;* in the third internodial space they are still larger, and two or three of them have become *punctuated spirals;* and the number of these increases as we descend in the examination of the stem. In the mature stem, near the centre, each fasciculus contains six *large punctuated spirals*, and near the root only six of the twenty-nine vessels in each fasciculus are simple spirals, all the rest being punctuated. The same phytologist also asserts, that as these vessels enlarge, their sides become thicker and more opaque, and a sort of cellular tissue is formed within them *. A similar variety in the number of the vessels which compose the fasciculi of sap vessels, occurs in almost all herbaceous plants; and my observations tend, also, to confirm Kieser's remarks respecting their augmentation in size; but I have not been able to satisfy myself of the correctness of his opinion, that the transformation of the simple spiral vessels is the cause of the diversity of character of the vessels in the different parts of the stem. I have not examined the Gourd; but in the stems of Bryony and of the Cucumber, which belong to the same natural order of plants, I have found the three distinct kinds of sap vessels, which I demonstrated to you in our examination of the structure of the stem of Bryony, in every part of

* *Mém. sur l'Organisation des Plantes*, p. 134.

the stem. We must, also, bear in mind, that, in his explanation of these diversities, Kieser has a favourite theory to support; and believes that the simple spiral is the original form of every vegetable vessel, whether annular or cribriform, and whether existing in trees and shrubs or in herbaceous plants. But the fallacy of this opinion is easily proved by a good microscope and attentive observation. I am even satisfied that the examination of the vessels in their united state in the fasciculi of herbaceous stems, often leads to erroneous conclusions; for, as the thread forming the spiral is more opaque than the membrane forming the membranous cribriform vessels, if one of these be mixed with several spiral vessels, it assumes a ribbed character owing to the spirals situated below or behind it being obscurely seen through its coat; thence we conclude that it is an annular vessel; and the error is detected only when we can fortunately separate the vessels from each other, and from the surrounding cellular matter, an operation which is extremely difficult. Thus, in my dissections of the stem of Bryony, the large vessels in each fasciculus always appeared as punctuated annulars, until accident enabled me to detach one of them from the connecting parts. It appeared, evidently, to be composed of a simple membranous coat, punctured in circles round the vessels (see Plate 9, fig. 7). With regard to the rigid membranous vessel,

which Kieser has named the annular spiral, I can form no idea of the possibility of its transformation from the spiral, the rings being entire and placed at the distance of their diameter from each other; whereas the spires of the simple spiral are in contact, and never appear otherwise unless the fibre be drawn out, which is very frequently the case in preparing the section of a stem for the microscope. The hypothesis of Kieser is certainly very imposing, from the simplicity with which it accounts for the varied form of the sap vessels in the fasciculi of herbaceous stems; but my observations prevent me from adopting his conclusions.

The proper or descending vessels are also of two different kinds, at least in respect of diameter, as is evident in the portion of a transverse section of the stem of Hemlock represented in Plate 9, fig. 8; but I have not been able to make out satisfactorily the characters of either, except that both are cribriform. Indeed, we can scarcely conceive in what manner these vessels could perform their functions, were their coats completely impervious; for, as they convey the sap, altered in its properties in the leaf, or converted into proper juice, or that fluid from which all the other secretions, and even the woody fibre, are produced, there must be some means of communication between them and the cells, in which these secretions are deposited: and this would be necessary

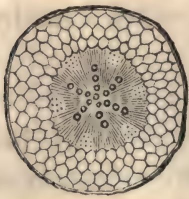
although the ultimate changes may take place in the cells; an hypothesis, however, which I am by no means prepared to admit.

Pursuing our inquiries into the structure of *herbaceous roots*, we find that the analogy between these organs and the stem is less close than in ligneous plants. This arises in many instances from the difference in the duration of the life of these parts in herbaceous plants; for the root may be biennial or perennial, when the stem or stems are annual only, or dying in the autumn and giving place to others, which rise from the same root in the succeeding spring.

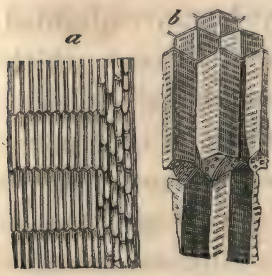
When the root is annual only, as, for example, that of the Sweet Pea, Lathyrus *odoratus*, it consists of a cuticle enclosing a thick cellular cortex, apparently devoid of vessels; and a central part, which is composed of a bundle of sap vessels, or rather of several bundles, arranged so as to form an irregular six-rayed star, embedded in a mass of small oblong cells, through which six fasciculi of proper vessels descend, almost touching the cortex, and situated in the spaces formed by the rays of the central fasciculus of sap vessels. The sap vessels are all punctuated spirals *; but those in the centre are smaller

* This is the only form of sap vessel I have observed in annual roots; and as Kieser, also, found punctuated spirals only

than those which constitute the rays of the fasciculus (see marginal cut). Such is the general structure of the majority of strictly annual stems; but they vary as far as regards the number of the rays of the sap vessels and the situation of the proper vessels.



The cells of the bark are, commonly, hexagonal, varying however in size; and those of the central part oblong, and apparently transversely furrowed; but the transparency of their coats renders it difficult to ascertain whether this furrowed appearance arises from oblong slits, opening from one cell into another, or from elevations perhaps of a glandular nature. In all the annual roots belonging to herbaceous plants, which secrete a white opaque proper juice, as, for example, the Poppy, Papaver *somniferum*, nearly the whole of the cells are oblong, or rather tubular; and are arranged with great symmetry, in the manner figured at *a*. (see marginal cut). A few cells very highly magnified are figured at *b*., chiefly to show the appearance of the lateral furrows or transverse slits, which




in the root of the Gourd, I am disposed to believe that the simple spiral is rarely, if ever, found in the annual root.

are very conspicuous in these cells. I have not been able to detect any fasciculi of proper vessels in roots of this description, and I am, therefore, disposed to believe that these tubular cells are not only the reservoirs, but the conductors of the proper juice. That they are endued with contractility, and communicate freely with each other, is evident: for, by making a horizontal section of the root, the exudation of juice is much greater than can be contained in the range of cells which is divided; and, by placing a longitudinal slice of the root under the microscope, we find the cells of several successive ranges empty and shrunk. That this longitudinal communication is regulated by valves, or something of a similar nature, is probable; for, the exudation of the juice is much more considerable on the divided surface, and the shrinking of the cells extends to more distant ranges, in the portion of the divided root which remains attached to the plant, than in that which is separated from it.

The disposition of the parts of the root is more varied in *biennial* than in annual roots. Taking the root of Burdock, Arctium *lappa*, as an example, we find that, in the first season of its growth, or in the seminal plant, it consists of a thick cellular bark, the cells of which are irregular hexagons arranged in concentric circles around a large central part, which is composed

chiefly of oblong cells, or rather short hexagonal tubes. These tubes in the transverse section appear arranged in beautiful rays proceeding from the centre to the circumference, and, in the longitudinal section, show nearly the same symmetrical ranks that have been described as existing in the Poppy root. The sap vessels are comparatively few in number, and are arranged in rays through the central part. They are larger than the cellular short tubes, which are condensed in the line of each ray of sap vessels, so as to produce a very beautiful appearance in a transverse slice of the root examined under the microscope. All the sap vessels are punctuated, but I have not been able to satisfy myself that they are spiral. In the second year, a new circle of short tubes is formed with some additional sap vessels interspersed through it, both preserving the radiated arrangement; the old bark appears lacerated, shrivelled, and pushed outwards, whilst the space betwixt it and the new central matter, is filled up with fresh cortical cells.

The short tubes appear to be the principal reservoirs of the mucus, with which this root abounds; but it is present in the cortical cells also, a lateral communication existing between these and the hexagonal tubes. It is apparently intended for advancing the fructification of the plant, being gradually absorbed as that process is

perfected; at which time the short tubes are emptied, and their sides gradually become ligneous and opaque.

The root of the Carrot, Daucus *carota*, resembles that of the Burdock in general structure, but the sap vessels are comparatively more numerous, and the cellular rays more condensed. The cells and short tubes are rather four-sided than hexagonal; and there is no symmetrical arrangement of the latter. The sap vessels are all punctuated, even the smallest and most recently formed, which militates against Kieser's opinion of transformation.

In the root of Hemlock, Conium *maculatum*, the sap vessels are situated chiefly in the centre, in fasciculi, interspersed with cellular matter, disposed in narrow wedgelike masses, divided by more condensed cellular matter, closely resembling the divergent rays in the roots of trees. The cortex is thick, and contains various fasciculi of proper vessels, disposed at regular distances, so as to form a kind of double circle. The sap vessels are punctuated spirals.

Such is the structure of these three biennial roots. The diversity they display is sufficient to demonstrate the variations in the position of the parts, which occur in biennial herbaceous roots. In all of them the proper vessels constitute the greater part of the bulk of the root; and appear

to be chiefly reservoirs of the proper juice formed by the first year's foliage, which is expended in the formation and perfecting of the flower-stem and the fructification, the productions of the second year.

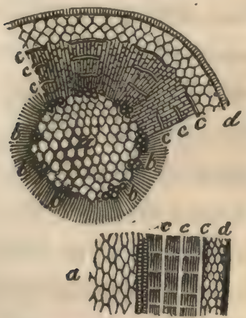
As the growth of the flower-stem, therefore, and the evolution of the flower advance, the root, instead of increasing in bulk, gradually shrivels, and becomes of a more ligneous texture, owing to the absorption of the proper juice and to the emptied state of the short tubes. On this account we find that those biennial roots, the Carrot and Turnep for example, in which the art of cultivation has so much increased the deposition of nutritious matter, as to render them important as articles of food to man and other animals, cease to be fit for this purpose very soon after the flowers of the plants to which they belong make their appearance.

The *perennial herbaceous* roots are still more varied in structure, as far as regards the proportion and arrangement of the vascular parts, than either the annual or the biennial. It would be impossible in this place to demonstrate even a very small proportion of those diversities: and these roots have been too little examined to admit of any classification founded on structure. I shall venture, however, to arrange them into two classes, the *first* comprehending those which, besides sap and proper vessels, are composed chiefly of short tubular

cells, which appear symmetrically arranged in the longitudinal section of the root: the *second*, those which consist of sap and proper vessels, and common cellular matter only, exhibiting no peculiar symmetry of arrangement in the longitudinal section.

1. *Perennial herbaceous roots composed chiefly of tubular cells symmetrically arranged.* As examples of this class, we may select the roots of Dandelion and of Marsh Mallow; because the principal secretion in the one is an opaque, white, glutinous fluid, and that in the other a transparent colourless mucus.

If we place a transverse and a longitudinal slice of the root of Dandelion, Leontodon *Taraxacum*, in



the first year of its growth, under the microscope, it appears composed of a cellular pith *a.* (see marginal cut), surrounded by ten fasciculi of sap vessels *b.*; and a very thick cortex, which consists, interiorly, of a concentric layer of smaller cells arranged in rays, through which run numerous fasciculi of proper vessels, *c.* arranged so as to form three concentric circles; and exteriorly of a mass of hexagonal cells, the same as the pith covered with a thick cuticle, *d.* The sap vessels are punctuated, the perforations being oblong trans-

verse slits; and the radiated cells are tubular and arranged in symmetrical order. The character of the proper vessels can scarcely be made out, owing to their transparency and the white juice with which they are filled; but they are evidently perforated and communicate laterally with the tubular cells, into which the juice they convey is filtered, to be preserved for the purposes of the plant. This juice probably undergoes some change in its passage, as it appears to be more pellucid in the tubular cells, than in the proper vessels.

As the root advances in age, additional vessels are added to the fasciculi of sap vessels, until the whole of the central part of the stem is nearly occupied with them; and, the original cellular matter being closely compressed between the fasciculi, the vascular portion assumes the aspect of one large fasciculus. Vessels are added exteriorly also; but these are much fewer in number, although they are larger and more distinct than those within the original circle. In the same manner a new layer of cellular tubes and of proper vessels is annually added to the bark, so that a transverse section of an old root appears to the naked eye to consist of an opaque woody central part surrounded with concentric circles, alternately opaque and transparent. The old cuticle, with a portion of cellular matter adhering to it, is annually pushed outwards, as in the trunks of trees,

and its place is supplied by a new one; but in this plant the cellular matter, which is found situated immediately under the cuticle in the young, is deficient in the old root.

The transverse section of the root of Marsh Mallow, Althæa *officinalis*, displays a kind of pith composed of one large fasciculus of sap vessels in the centre, surrounded by a mass of cells arranged in rays, having a few small fasciculi of sap vessels dispersed through it; and several larger on its verge, forming an interrupted circle round it. The cortex is thick, cellular, and contains clusters of proper vessels arranged in a radiated form. In the longitudinal section we find that the sap vessels are punctuated, but not spiral; and the tubular cells are comparatively much shorter and wider than those in the root of Dandelion; a circumstance which appears almost to be essential, when we consider the nature of the mucilaginous secretion deposited in them.

In both these roots the central part readily separates from the cortex; and, except in very young roots, it is from the latter only that we can extract the secretions on which their value as medicinal agents depends.

2. *Perennial herbaceous roots composed chiefly of common cellular matter.* The root of Deadly Nightshade, Atropa *Belladonna*, may be taken as

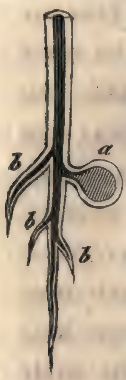
an example of the general structure of this division. It is composed of a central part and a very thick bark. Placing a transverse section of the young root under the microscope, we find that the central part consists chiefly of cellular matter postured in a radiated manner, with one large fasciculus of sap vessels in the centre, and several smaller fasciculi interspersed through it, forming nine or ten indistinct, interrupted rays. In the root of the second year, the additional sap vessels appear as an interrupted circle bounding the central part; and in older roots, as new circles are annually added, the transverse section resembles, in some degree, that of a ligneous stem; or it appears to consist of a pith, concentric circles of wood traversed by divergent rays, and a bark. In the longitudinal section we perceive that the sap vessels are punctuated, but certainly not spiral; and that the cells are oblong, but not arranged in the symmetrical manner, which characterizes the former division of the roots under examination. Decorticating the root, we perceive, also, that the fasciculi of sap vessels do not run in straight lines, but take a waving course; and by vessels separat-

ing from one fasciculus coming in contact with those separated from another, the whole appears like a reticulated texture on the surface of the central part (see marginal cut); a circumstance, however, which is not peculiar to this root, but is

general to all herbaceous roots in which the central part consists of rather more cellular than vascular matter.

Such is the general structure of herbaceous roots. The main caudex in every instance is more or less of a spindle shape; but it frequently becomes forked near the apex, in which case there is a separation of the sap vessels, in the same manner as occurs in dividing a skein of threads into two or three parcels; each fork of the root containing a portion of the vessels belonging to the main body of the root. In the lateral branches or rootlets, however, this is not the case. These are generally given off at right angles with the main root; and each is composed of one large fasciculus of sap vessels enclosed in a cellular cortex; but very few of these vessels are given off from those of the caudex; the majority being new vessels generated in the *puncta vitalia;* in which the rootlets originate. Whether these new vessels anastomose (using the expression as it is employed in speaking of animal vessels) with the vessels of the main root, I have not yet been able to satisfy myself; they are evidently closely applied to and lost on the surface of the fasciculus of the caudex whence they originate, and pour their contents into it; but this might be effected without an anastomosis, by the lateral transmission through the punctures in the coats of the vessels.

In general, the lateral rootlets extend in the direction of their axis, and display an uniform structure throughout their length; but this is occasionally altered by the nature of the soil. Thus, on the root of the common Sweet-pea, Lathyrus *odoratus,* when cultivated in a dry soil, we frequently find that the rootlets, instead of extending as fibres, swell and assume all the external characters of knobs; which, however, differ from tubers in being merely reservoirs of nutriment, without containing the germs of future buds. When one of these is dissected, the vessels are seen to originate as in the other rootlets, but they soon divide,




and embrace the cellular mass which contains the nutritious matter, of which the knob is the reservoir (see marginal cut, in which *a.* represents the knob, and *b. b. b.* the natural radicles). The explanation of the formation of these occasional knobs on herbaceous roots, advanced by Sir J. E. Smith, does not now appear to me so satisfactory as I formerly supposed it to be (page 206); for I find that they appear on the roots when "no sudden fresh supply of food is furnished." It is probable, also, that such a supply, if made to a half-starved plant, the roots of which as yet display no knobs, would occasion the natural extension of the rootlets, instead of producing

knobs. It appears to me, that when an herbaceous plant is partially stinted of moisture and nutriment in the soil, the functions of some of the rootlets are destroyed, owing to the sap vessels losing their irritability and becoming obstructed; while at the same time the absorbing orifices of the cuticle become also impermeable. But as the other rootlets still continue in a natural state, the plant is kept alive; and as the proper juices are secreted, the usual supply is sent to the affected rootlets, which, however, not being able to assimilate it, the cellular matter in which it is deposited swells, and the rootlets assume the character of the knobs in question *.

From the examination of the structure of herbaceous roots, which we have just concluded, several practical hints may be obtained. Thus it appears probable, that those roots, containing bland saccharine or amylaceous secretions, which possess a moist cellular central part, are the best adapted for rewarding the skill of the horticulturist, in converting them into articles of food for man and other animals. We also discover the reason that

* Mr. Keith says, "This anomaly seems to be merely the "result of a provision of Nature, by which the plant is en- "dowed with the capacity of collecting a supply of moisture "suited to existing circumstances, and hence of adapting itself "to the soil in which it grows." *Syst. of Phys. Bot.* vol. ii. p. 271.

the central parts of some medicinal roots are as valuable as the cortical; although, in general, the bark is that part of the root which is most richly stored with the proper juices of the plant. In examining unknown roots, when we find the central part woody, we may always conclude that it consists entirely of sap vessels, and therefore is useless either as food or as medicine; but when it is composed chiefly of a moist, cellular substance, we may expect to find it useful, from having some of the proper juice and secretions of the plant deposited in it. The ignorance of this fact, led Pharmacopolists, until very lately, to expend unnecessarily much labour and time in preparing several vegetable decoctions and extracts, as, for example, the decoction of sarsaparilla; for the preparation of which the root underwent long macerations and much boiling, from an idea that its virtues were contained in the ligneous central part; whereas the saponaceous mucus for which it is valued, is deposited solely in the cortical part, and can be entirely extracted by cold water.

In selecting the proper period for digging up roots for medicinal purposes, it ought to be recollected that, as the proper juices which are stored up in the roots of such plants as produce leaves only in one year, and then flower and die in the second, are expended in the process of fructification; biennial roots should be taken up at the

end of the first season of their growth, for then the cells are turgid with the secretions. Perennial roots, also, should be dug up before the central part becomes ligneous; for, as these roots increase in diameter by annual additions to both their central and cortical parts, in the same manner as the stems of trees, the interior of the central part becomes every year more and more inert, and ultimately decays; so that, in employing such roots, when old, even before they decay, the active principle they contain becomes too largely diluted with the inert matter to answer the purposes expected from them as drugs.

In closing our researches into this part of Phytotomy, the anatomy of stems and roots, I may observe that the subject has, hitherto, been imperfectly examined; although the field of investigation is very extensive, and the harvest it contains calculated to repay amply the toil of the most assiduous labourer. The improvements which are daily making in the construction of the microscope, are likely soon to set aside all the obstacles depending on the minuteness of the parts; and a very little experience is sufficient to make the student expert in the use of this instrument. The best authors to be consulted on the subject are *Grew*, Anatomy of Plants; *Malpighi*, Anatome Plantarum; *Rudolphi*, Anatomie der Pflanzen; *Kieser*, Mémoire sur l'Organisation des Plantes;

*Mirbel*, Elémens de Physiologie végétale; *Comparetti*, Prodromo de Fisica vegetabile; *Du Hamel*, La Physique des Arbres; *Hill* on the Construction of Timber; *Krocker*, Diss. de Plantarum Epidermide; *Bauer*, Tracts relative to Botany, London, 1809; *Bölimer* de Vegetabilium celluloso Contextu; *Reichel* de Vasis Plantarum spiralibus; Histoire d'un Morceau de Bois, &c. par *A. A. du Petit Thouars*; *Keith*'s System of physiological Botany; Supplement to the Encyclopædia Britannica; and Mr. Knight's papers in the Philosophical Transactions.

# LECTURE IX.

OF LEAVES—IN THEIR UNEXPANDED STATE, OR AS THEY ARE CONTAINED IN THE GEM:—IN THEIR EXPANDED STATE, OR AS CONSTITUTING FOLIAGE.

Having concluded our examination of roots, stems, and branches, we are now prepared to investigate the structure of *leaves*.

In winter, while the power of vegetation is inactive, and the groves and forests present the desolate appearance of naked stems and branches, the majority of trees, shrubs, and many other plants may be regarded as existing in a state of torpor, similar to that which some animals experience in the same season. During this period the leaves are enclosed in small pyramidal bodies, either projecting from the surface of the stem and branches, or seated upon the roots; and in this state they remain until the warmth of the vernal sun, again rousing into action the vegetable functions, enables them to burst open their coverings, and clothe the woods anew in all the luxuriance of foliage. In our examination of leaves, therefore, we must regard them both as they are shut up in these

*hybernacula*, or winter habitations, and in their expanded state.

The pyramidal bodies which I have just noticed are well known by the name of *buds;* and the appellation is so universally applied in this country in reference to their appearance on trees in early spring, that it would be pedantic to reject it; besides, I have already used it in speaking of the origin of branches. But as the term bud is also employed to denote the separate flower before it blows, and as the purposes of science are better attained by using a word applicable to the object only which it is intended to present to the mind, I shall employ the term *hybernaculum* as synonimous with bud, in treating of this part of our subject.

A HYBERNACULUM may be defined: an organic body which sprouts from the surface of different parts of a plant, enclosing the rudiments of the new shoot; and which is capable of evolving a new individual perfectly similar to the parent. This is a modification of the definition of Gærtner *, which

* "An organic body generally sprouting from the surface "of a plant, without previous fecundation; in the beginning "distinct from the peculiar and permanent membranes of the "plant; but which, in a certain time, either becomes a part "of the parent, or separates from it, and by the increase of its "own substance becomes a new plant, closely resembling the "parent." *Gærtner de Fructibus Plant.* p. 3.

is objectionable only in expressing an opinion, as to the early state of the bud, that may be disputed*. Some hybernacula remain attached to the parent; others detach themselves after a certain period, but both kinds are to be regarded as the lateral progeny of the plant; for even that which remains attached possesses, in a certain degree, a separate or distinct vitality, by which it is enabled to exist when forcibly detached from the parent. Thus a bud taken from a tree, and properly planted in the ground, covered with a glass to prevent too great an exhalation of its natural moisture, will grow and become a tree resembling, in every respect, that from which it was taken. But still the plant, whether raised from a bud thus forcibly detached, or from one which naturally detaches itself, is an extension only of the parent, displaying all its individual peculiarities the effects of soil or culture, and inheriting all its diseases; whereas a plant raised from a seed is a new individual, displaying the generic and specific characters only of the parent. From the same cause, also, plants which are natives of a warm climate, when taken to a colder, and pro-

* "*Hybernaculum* est pars plantæ includens herbam em-"bryonem ab externis injuriis." *Phil. Bot.* § 85. The admirable simplicity which characterizes all Linnæus's definitions is here conspicuous; but the definition is objectionable in being equally applicable to the seed as to the hybernaculum.

pagated by slips or buds, never become so completely naturalized as to bear all the variations of the new climate with impunity; but plants which are propagated by seeds, although natives of very warm climates, yet, become perfectly naturalized to colder in a certain number of generations.

Botanists enumerate three kinds of spontaneously separating Hybernacula, the *Propago*, the *Gongylus*, and the *Bulb;* and one which does not spontaneously separate from the parent, the *Gem.*

The PROPAGO * is thus defined by Gærtner:— "A simple leafless, polymorphous, or variously "shaped germ, in some instances naked, in others "enclosed in a cortical sheath, which sponta- "neously separates from the parent, and is scat- "tered in the manner of seed." It is a small pulpy or cellular body of no regular shape; and is sometimes covered with an epidermis. It is readily found in dividing the tubercles and shields or saucerlike bodies, which appear on the surfaces of Lichens, in an early stage of their

* This term was used by the ancients chiefly to denote a cutting of the Vine, when buried in the ground to throw up new shoots; but it was applied also to cuttings of other plants. Arbores aut semine proveniunt, aut plantata radice, aut *propagine*, aut avulsione, aut surculo, aut insito et consecto arboris trunco. *Pliny*, l. 17. c. 10.

growth. According to Gærtner all the Algæ are propagated by the propago, and not by seeds as Hedwig and other phytologists have asserted. With such names as contending authorities on this subject, may we venture to suggest, that although the sexual organs of these plants have not yet been discovered, and although they throw off the propago as lateral progeny, yet they may, also, produce real seeds? Many of the more perfect plants are propagated in both ways; and we know that this occurs even in the animal kingdom; for the aphis which is first propagated by sexual intercourse continues its species, through several successive generations, by lateral offsets.

"The GONGYLUS," according to Gærtner, "is "a simple, leafless, somewhat globular, solid "germ attached to the parent under the bark, "and separating spontaneously from it." He observes that it has a close affinity to the tubers found on roots; but differs inasmuch as the tuber possesses as it were a multiplied life, so that it may be divided into as many pieces as there are foliaceous gems on its surface, from each of which a new plant will arise. The gongylus consists of cellular matter like the propago, but of a much firmer and more solid consistence, and is always covered with an epidermis. Gærtner supposes that the Fungi, or Mushroom tribes, are altogether propagated by gongyli: but Michelius, Hedwig, and

Bulliard detected their seeds; and there is every reason for believing that these and many of the other tribes of lower plants produce both seminal and lateral progeny.

The BULB having been already defined (p. 164), and also described as it appears attached to the roots of plants; we have now to examine it only as it appears upon the stem *. It is found on the stems of several species of the Lily, on that of bulbiferous Coralwort, Dentaria *bulbifera*, and of drooping Saxifrage, Saxifraga *cernua*, &c.† seated in the axilla of the leaves (Plate 4, fig. 9, *a. a.*). If we take the Tiger Lily, Lilium *tigrinum*, as an example, we shall find the bulbs appearing like a white speck in the axilla of the leaves long before these expand. A few days, however, after the expansion of the leaf the bulb assumes a pyramidal form, which gradually enlarging and swelling in the centre, at length appears of an ovate or nearly globular shape, with a keel terminating in a point. During this transformation

* Mirbel denominates the caulinar bulb, Bulbille, *Bulbillus*, and thus defines it: "Petite bulbe qui nait sur différentes par-"ties de la plante hors de terre, se detache et prend racine." *Elémens de Phys. vég.* Partie 2, p. 634.

† Sir J. E. Smith says he has seen bulbs form on the flower-stalk of three-coloured Lachenalia, Lachenalia *tricolor*, whilst lying for many weeks between paper to dry; and these on being put into the ground have become perfect plants, though of slow growth. *Introd. to Botany*, p. 112, note.

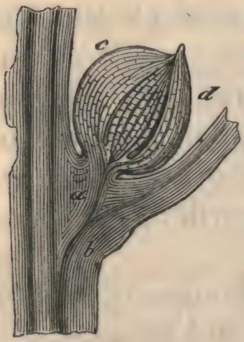
it also acquires colour on that part of the surface exposed to the light; passing first from white to green, then to light brown, and lastly to a very deep shining jet brown. On attaining this degree of maturity it separates from the stem on the slightest touch, or it spontaneously loses its hold; and, dropping to the ground and vegetating, throws out roots and acquires all the characters of a root bulb. Linnæus, nevertheless, regarded the caulinar bulb as a gem, and denominated it *Gemma decidua**; but, independent of its spontaneously separating from the parent, which the real gem never does, it differs in other essential characters from the gem.

Examining one of these bulbs in a mature state, we find at its lower part a depression resembling the hilum or scar, which on a seed points out the place of its attachment in the seed-vessel. It consists, in the bulb, of a depression enclosing three elevated points, which indicate the place where the vessels connecting it with the parent entered. The bulb itself consists of two outer scales, the uppermost large and embracing the lowermost, which projecting forms the keel of the bulb, and embraces another scale within it, which in its turn embraces a fourth, and so on to

* Species Gemmarum variæ sunt, *Deciduæ* in Dentaria, Ornithogalo, Lilio, Saxifraga. *Phil. Bot.* § 85.


the germ or embryon. This structure is illustrated in the marginal cut, which displays a transverse section of the bulb very considerably magnified: *a.* is the uppermost or largest scale, composed of a mass of cellular matter enclosed in a cuticle, with seven fasciculi of vessels, as marked by the dots where they are divided, running through it; *b.* the second or lowermost, or keel scale, with its vessels; and within it are the third, fourth, and fifth scales, each embracing the one within it. The whole of the cells are filled with minute amylaceous granules, mingled in a clear, viscid mucilage; the opacity of the fluid being greater in the outer scales and diminishing in a direct ratio as these approach the centre of the bulb. Each scale is covered with a beautiful, readily separating epidermis.

Making a longitudinal section of the stem of




the Lily, so as to divide a bulb, *in situ,* directly through its axis, we find that the fasciculus of vessels *a.* (see marginal cut) which nourishes it, and which may be regarded as its umbilical cord, is a portion of the bundle *b.* which is given off to supply the leaf. As it ap-

proaches the bulb, it divides into three fasciculi, one of which enters the upper scale *c.* where it splits to form the seven fasciculi that run through it, as has been already demonstrated; another passes into the keel scale *d.* and the third subdivides to supply the interior scales and the embryon. The conducting vessels are all simple spirals; but I have not been able to determine the character of the returning vessels. When the bulb is perfected it separates from the stem, as has been already mentioned, in the same manner as ripe fruit falls, the umbilical vessels dividing at the point of attachment.

Caulinar bulbs when planted produce leaves only, like those formed on the separated scales, or raised from the seeds of the Lily; and like these, also, they exhibit all the peculiarities and diseases of the parent.

From the analogy which we recognise between the sexual progeny of animals, and the seminal progeny of vegetables, we are accustomed to regard the distinct vitality of seeds and their retention of life as a matter of course; and even persuade ourselves that we comprehend the manner in which the principle of vitality is conveyed to the embryon; but, although bulbs resemble seeds in many respects, yet as they are not the result of the sexual functions, we find much difficulty in comprehending how they acquire and maintain

that individual vitality, which is necessary for preserving them in a state fit for vegetating, after their separation from the parent, and before they are planted in the ground. It would be anticipating the arguments I have to advance on the causes of vegetable reproduction, were I to enter largely into the consideration of this subject at present; but I may observe that, whether the progeny be direct or lateral, a certain organization, whatever that may be, peculiar to the species to which the individual belongs, is requisite for retaining the vital principle in conjunction with matter, and this is found in the bulb as well as in the seed. In both, the embryon is to be regarded not as a part only, but as a compendium of the whole of the parent; and the organization is so complete in every part, that the separation from the parent effects no change in it; and, consequently, as long as no change occurs, both the bulb and the seed continue fitted for commencing the vegetating process, when placed under circumstances favourable for that event. But it may be argued that a small portion of a polypus will increase and become a perfect animal, and twigs of the Willow, the Vine, and of some other plants, after being separated for a considerable time from the parent, will vegetate if thrust into the ground and left there. We know too little of the nature of polypi, to explain the multiplication of the animal from cuttings, but it is probable that the vegetation of the twigs re-

ferred to, depends on the organization of the germs contained in the buds of these plants approaching to that degree of perfection which is found in bulbs and seeds. It may, however, still be demanded how is this perfect organization accomplished in bulbs? In seeds, while in the state of ovula, the peculiar stimulus of the pollen may produce a specific action capable of evolving all the parts of that peculiar structure, with which we find vitality connected; but in bulbs we can scarcely suppose that the vital action which completes their organization differs from that by which a gem, or branch bud, is formed; and yet buds, when separated from the parent stem, will not live, unless they are either immediately planted, or inserted into another stock of a structure resembling that of the parent. A question thence occurs (admitting that all plants which throw off lateral progeny as bulbs, propagines, and gongyli, possess sexual organs, and, therefore, are capable of being also propagated in a direct way), namely, can any of the impulse communicated by the sexual functions influence the lateral progeny? That such an influence exists is probable, if it be allowable to reason analogically and refer to the animal kingdom; for we find that from the egg of the aphis, which is laid in the autumn, and is the result of the sexual intercourse of males and females, a young insect is produced in the spring; which after casting its skin once or twice, pro-

duces a living progeny without sexual intercourse; and "this offspring produces others by this solitary "propagation, till the tenth generation; then a "sexual progeny of males and females is produced," and eggs are laid from their copulation*. Now, although no experiments have been made to ascertain how long a bulbiferous plant may be propagated by bulbs only, checking every effort for the production of seed, yet, we know that in bulbiferous plants, when the production of bulbs is considerable, the seeds are seldom ripened, and even the sexual organs are often defective; and the reverse happens when the production of bulbs is either scanty or defective. The analogy between the successive lateral generations of the aphis, before males and females are formed to recommence the propagation by eggs, and the progressive formation of bulbs before a flower-bulb is the result, is still more striking. The bulb, which is raised from the seed, produces one or two leaves only, and bulbs one degree more perfect than itself; which in their turn yield stronger plants and more perfect bulbs; and in this manner a succession of leaf-bulbs are annually evolved for four or five years, till at length a flower-bulb and a seminal progeny are produced. The vegetable, however, differs from the animal in producing, at the same time with the flower-bulb, other

* *Amœnit. Academ.* vol. vii. *Darwin's Phytologia,* § ix. 3, 1.

leaf-bulbs also; so as still to secure its preservation should its flowers be accidentally destroyed.

Such are the separating Hybernacula. Although they resemble seeds in containing within them a perfect embryon, yet, like that contained in the attached buds, which we are now about to examine, it is an offset or continuation only of the parent, and not a renewal of the species. Many of these plants which have been improperly named imperfect, as for example the *Confervæ* and *Lichens*, are supposed to be propagated by no other means; but as the plants thus produced display not only the essential, but the accidental characteristics of the parent, I am disposed to believe, as I have already stated, that the "propagation "by seed is, in their case," by no means, "out "of the question *."

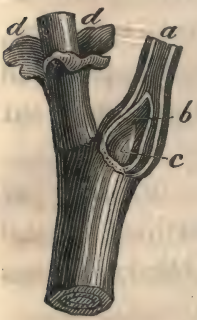
The attached Hybernaculum, or *bud*, or GEM †, as it is more generally termed, is a small oval or pyramidal body, enclosing the rudiments

* *Elements of the Philosophy of Plants*, by A. P. Decandolle and K. Sprengel, § 302, *Eng. Trans.*

† The ancients used the terms *Germen* and *Oculus* to denote those buds which contain the rudiments of branches and leaves, and *Gemma* those in which flowers only are contained; but by the moderns, *Germen* has been applied to denote the rudiment of the fruit; thus, Linnæus, Germen rudimentum fructus immaturi in flore (*Phil. Bot.* § 96), or as a generic term for all buds (see Gærtner *de Fructibus*), while *Gemma* is employed exclusively to indicate caulinar buds.

of branches and leaves, and sometimes flowers, and never separating from the parent *.

Gems are found on all trees and shrubs in temperate climates. In the majority of instances they are visible from the first, in which case they are axillary, that is, seated in the axillæ of the leaves, or the angle which the upper part of the footstalk of the leaf makes with the surface of the stem; and *terminal*, or at the extremities of the branches: but in some instances, for example, the Sumachs, *Rhus*, and the Planes, *Platanus*, they are *latent*; being hid within the base of the footstalk, and never seen until the fall of the leaf. In the marginal cut, *a.* represents the footstalk of a leaf of the Oriental Plane, Platanus *orientalis*, split longitudinally to show the cavity *b.* in which is seated *c.*, the gem. Gems are, however, sometimes protruded from the trunk, long after it has ceased to produce



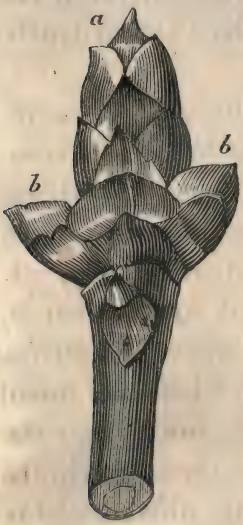

* The above definition is a modification of that of Gærtner, who thus defines the gem, "a compound subulate or pyramidal "germ, with manifest herbaceous leaflets, containing the rudi- "ments of branches, and never separating from the mother." Linnæus's definition is less correct, "Gemma est hybernaculum "caudici adscendenti insidens. Constat vel stipulis, vel "petiolis, vel foliorum rudimentis, vel squamis corticalibus." *Phil. Bot.* § 85, 2.

leaves, as in the case of adventitious buds, already treated of; they are also situated on roots, and on tubers; but in these cases they are usually denominated *eyes, oculi.* Annual plants are supposed not to be furnished with gems; but although they are devoid of covered gems, yet their lateral shoots proceed from naked buds, which immediately spread into foliage.

The relative position of *axillary* gems is necessarily regulated by that of the leaf; and therefore we find them, 1. *opposite,* or placed exactly on the same line on opposite sides of the stem or the branch; 2. *alternate,* or placed alternately, although on opposite sides; and 3. *spiral,* that is, placed round the stem or the branch in such a manner, that a cord wound in a spiral manner round it would touch each gem. They are said to be *simple* or *solitary,* when one gem only is seen in the axilla of each leaf, as in the greater number of instances; and *aggregate,* when, as in some plants, two, three, and even more, are protruded at the same time: thus we find two on the common Elder, Sambucus *nigra,* three on broad-leaved Birth-wort, Aristolochia *sipho,* and on Blue-berried Honeysuckle, Lonicera *cærulea,* and many on common Toothach tree, Zanthoxylum *fraxineum;* but as these are natives of cold countries, it is supposed that the intention of Nature in this double and triple supply is to secure the plants

against the effects of frost, and other accidents of climate to which their situation exposes them. In this climate, however, one of the additional buds is always evolved the same season in which it is protruded.

Du Hamel first noticed the fact, that stems




and branches furnished with alternate axillary gems, have generally one *terminal* gem only, and those with opposite have generally three terminal gems. In the Horse Chesnut the middle terminal gem is the largest (see *a.* in the marginal cut), and bursts soonest into foliage; while those on its sides (*b. b.*) are much smaller, and sometimes never open, but decay and drop from the branch. In the Lilac, on the contrary, the middle terminal gem is always the smallest, and scarcely ever pullulates. In some trees, as for example the Pine tribe, all the gems are terminal.

The gems on most trees and shrubs rise with a broad base from the surface where they are protruded, and, consequently, being in close contact with it, are said to be sessile *(sessiles)*; but they are distant or stalked on some; as for example, the common Alder, Alnus *glutinosa*, on which

they are supported on a short footstalk, and are then termed stalked *(pedicillatæ)*. In employing these terms, however, the student must bear in mind, that they refer to the entire gem; for a writer of great merit, in describing the gem, says, it "is connected with the stem or branch by means "of a short and fleshy pedicle, in which the "scales originate *;" whereas this is merely the base of the young branch it encloses. The angle, also, which gems form with the stem or branch, varies considerably in different trees; thus on the Willow they lie almost parallel to it, while on Apple and Pear trees they project so as to form nearly a right angle with it; but by this the direction of the future branch is regulated.

Let us detach a gem from any tree, for instance the Horse Chesnut, which affords the most magnificent specimen of a gem known in this country, and examine its structure. We find that it consists exteriorly of eight pairs of hollow scales, each pair consisting of scales of the same form and magnitude, placed directly opposite to each other, in such a manner as to cover the opposing edges of the pair within them. The inner scales are longer, and more tender and succulent than the outer, which are hard and covered with a viscid resinous exudation, that unites them together, and is found

* Keith's *Syst. of phys. Bot.* vol. i. p. 65.

on the inner scales also; but of a thinner and more transparent quality. On removing all the scales, the rudiments of the young branch and the leaves are discovered, embedded in a soft hairy or woody substance. If this examination be made, by dividing a terminal gem longitudinally, in the very early part of spring, before the buds begin to swell, we find (see *k.* fig. 15, Plate 5) the rudiment of the new branch apparently quite distinct from the old; separated by a partition which, as the season advances and the scales begin to open, is gradually obliterated, while at the same time the quantity of woolly matter surrounding the leaves is greatly increased, and these acquire their determinate forms, folded up, however, so as to occupy the smallest possible space. But although the examination of any gem will afford a general idea of the structure of all, yet, gems differ very considerably in the number and characters of the enclosing scales, their contents, the folding up of the leaves within them, and the manner in which these are evolved in the spring.

*a.* The *scales* which constitute, in fact, the hybernaculum, differ, as has been already stated, in size and texture even in the same gem; in the gems of different plants they differ also in number and in the nature of their coverings. Some gems, indeed, are entirely destitute of scales, for example, those of annual plants, and of many

perennials of tropical climates, in which the interval between the formation and the evolution of the bud is so short as to require no protection for the young shoot.

The scales in some instances are smeared with a resinous matter; in others they are perfectly free from any moist exudation, but are smooth and polished, being covered with a dry gummy varnish; or they are externally hairy, or enveloped in a velvety down. In their organic structure, they closely resemble the scales of bulbs, being composed of a layer of cellular substance, enclosed in an epidermis, and containing fasciculi of vessels running in lines from the base to the apex. The vessels enter the scale in distinct fasciculi; and to this arrangement is attributed the difference in figure which always exists between the scale and the real leaf, into the latter of which the vessels enter in one fasciculus only, from which, as from a common centre, they are distributed through the leaf.

The inner scales perform the functions of the leaves until several of these are expanded, and then they generally drop off; displaying in this respect a striking analogy to seed lobes, which, in many seeds, rise above the surface of the ground, and become green, executing all the functions of leaves until these attain a certain degree of maturity; after which they shrivel and fall. The

period at which the scales drop, differs in different plants; in some, as the common Lilac for instance, the more succulent inner scales remain attached until the shoot has attained to a considerable length; whereas in the Lime tree, Tilia *Europea*, they drop before the leaf is fully expanded. Gems are scarcely ever formed in the axillæ of the scales.

Gems differ in their characters in the same family of plants *, and even when found on the same tree; and, as the external form of the gem indicates the nature of its *contents*, Botanists have arranged them into three species, leaf-gems, flower-gems, and mixed gems.

1. Leaf-gems, or buds *(Gemmæ foliiferæ)*, are long, slender, tapering, and acute, generally containing, besides leaves, the rudiments of a shoot, on which account they are also termed wood buds; and are, in truth, embryon branches †.

* "Gemmæ in eodem genere sæpe diversissimæ, uti constat "ex genere *Rhamni*, ubi *Cervispina*, *Alaternus*, *Paliurus*, "*Frangila*, gemmis diversæ sunt." *Phil. Bot.* § 278.

† On this fact is founded the process of budding or inoculation, which is generally performed in July and August, and is preferred to grafting for such trees as are liable to exude much gum. To perform the operation, a transverse incision is made in the bark of the stock through to the wood; then a longitudinal one downwards, so that the two incisions shall resemble the letter T; and, lastly, the bark on each side of the longitudinal incision, is gently raised with a flat instrument, or the handle of the pruning-knife. The bud to be inserted should be selected from the middle of a shoot, and being separated with a slice of the bark about an inch above and below it, the

2. Flower-gems (*Gemmæ floriferæ vel fructiferæ*) are short, thick, swelling and rounded at the apex. Whenever the fruit ripens, all the parts protruded from a flower-bud die, but those from a leaf-bud give a permanent addition to the tree.

3. Mixed gems (*Gemmæ mixtæ vel foliifero-floriferæ*) are intermediate in respect to form; but generally larger than either of the other kinds†.

The Peach tree, Amygdalus *Persica*, the Mezereon, Daphne *Mezereum*, and many other plants, afford examples of distinct leaf and flower gems; the Lilac and the Horse Chesnut of mixed gems; and Pear and Apple trees of both leaf and mixed gems. The marginal cut represents the twig of a Pear tree, in which *a.* is


leaf is then to be cut off, leaving half an inch of the stalk; and any wood that may remain attached to the bark, must be stripped off by pulling it downwards. The lower part of the bark, attached to the bud, is now to be introduced into the cross incision in the stock, and pushed downwards: and, the upper part being cut across, the bark of the bud and that of the stock are brought into close contact. A piece of bass tied round the stock over the incision is the best mode of securing the bud in its place; and on loosing it, about three weeks after the operation, if the bud appear swelled and the footstalk of the leaf drop off, the operation has succeeded.

† Linnæus enumerates seven species of gems: "Deciduæ, in

a leaf or branch gem; and *b. b.* are gems which produce a small tuft of leaves terminated by a bunch of blossom. The information afforded by the external characters of gems is important to the practical gardener, in pruning fruit-trees in winter and in early spring; for, without it the whole of the floriferous gems might be destroyed, and the expectations of the cultivator altogether disappointed. But change of soil or of climate, the art of the horticulturist, and many accidents, may change one kind of gems into the other kinds. Thus a Solandra, Solandra *grandiflora*, in the Kew garden, which had never flowered, being by an accidental neglect left without water, the too luxuriant growth of the plant was checked, and flower-buds were formed in the ensuing summer *. From the same cause, a tree newly transplanted, is often covered with blossoms, although it be nearly destitute of foliage.

The leaves, as has already been mentioned, are variously folded up, so as to occupy the smallest possible space within the hybernaculum. This regulates the expansion of the leaves when

"Dentraria, Ornithogalo, Lilio, Saxifraga. *Foliiferæ, non floriferæ:* Alnus. *Foliiferæ, et floriferæ distinctæ:* Populus, "Salicis species, Fraxinus. *Foliiferæ et floriferæ femineæ:* "Corylus, Carpinus. *Foliiferæ et floriferæ masculæ:* Pinus, "Abies. *Foliiferæ et floriferæ hermaphroditæ:* Daphne, Ulmus, "Cornus, Amygdalus. *Foliifero-floriferæ*, ut pleræque arbores." *Phil. Bot.* § 85.

* *Smith's Introduction*, p. 190.

the gem opens in spring; and it is invariably the same in individual plants of the same species. The process is termed FOLIATION *, and the figures which the leaves assume at the time, have received different appellations. In noticing these I shall arrange them under the three following heads: *α Folded, β Overlapping,* and *γ Rolled;* and mention the varieties of each kind. The best method of ascertaining the character of a gem, as respects its foliation, is to cut it across while it is opening, and to examine the sections of the leaves.

*α. Folded.* This kind of foliation displays the leaf or its parts variously doubled together. There are two varieties of it: the *doubled* and the *plaited.*


1. In the doubled *(conduplicata)*, the two sides of the leaf lie parallel to each other, as exemplified in the Oak, the Walnut, the Cherry, the Beech, the Rose, &c. In the marginal cut, *a.* shows the section of a leaf, and *b.* the entire opening gem of the Lime tree, Tilia *Europea,* which is an excellent illustration of this variety.

* FOLIATIO est complicatio ea, quam servant *folia,* dum intra Gemmam aut Asparagos plantarum latent. *Phil. Bot.* § 163, iv.

2. In the plaited *(Plicata)*, the leaf is folded up like a fan; as exemplified in many of the Palm tribe; in the Birch, Betula *alba*, and Lady's-Mantle, Alchemilla. In the marginal cut, *a.* represents an unexpanded leaf of Alchemilla *alpina*; *b.* its transverse section.

β. *Overlapping*. Under this head are arranged those gems in which the margins of the leaves overlap those within them, or opposite to them, without being rolled. It comprehends the three following varieties.

1. The Imbricate *(Imbricata)*, in which the edges of two opposite leaves touch each other, embracing those within them, which they cover like tiles. In some instances the edges of the one leaf extend a little over those of that to which it is opposed; while in others the opposed edges scarcely touch. This variety is exemplified in Privet, Ligustrum *vulgare*, and Lilac, Syringa *vulgaris*, &c. In the marginal cut, *a.* represents the opening gem of Lilac, and *b.* its transverse section.

2. The Equitant *(Equitantia)*, in which the leaf is so folded, that the two sides


deeply embrace the opposite leaf, which in its turn encloses the one opposed to it; and so on to the centre of the bud. It is beautifully exemplified in Day Lily, Hemerocallis; in the Iris family; and in Solomon's Seal, as represented in the marginal cut, in which fig. 1. shows the character of the entire bud, with the leaf *a.* embraced by the opposite one *b.*; and fig. 2. the transverse section in which *a. b.* and the other leaves are drawn slightly asunder, so as to show more distinctly their arrangement.


3. The Obvolute *(Obvoluta)*, in which one leaf, doubled lengthways, embraces within its doubling one half of the opposite leaf, folded in the same manner; as in the genus Valerian, Valeriana; Scabious, Scabiosa; Teasel, Dipsacus; and Sage, Salvia. In the marginal cut, *a.* represents the opening bud of Common Sage, *b.* its transverse section.

$\gamma$. *Rolled.* This division contains all those gems in which the leaves are rolled, either on their lateral margins, or from the apex to the base. There are five varieties of this form of foliation.

1. The convolute *(Convoluta)*, in which the leaf

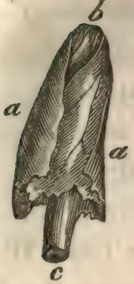
is rolled lengthways in a spiral manner, one margin forming the axis round which the other turns, as in the Plum genus, Prunus; the Lettuce tribe, Lactuca; the Cabbage, Brassica, and many Grasses, &c. In the marginal cut, *g*. displays this form of foliation in a section of the unrolled leaf of Indian Corn, Zea *Mays*.


2. The Involute *(Involuta)*, in which each lateral margin of the leaf is rolled inwards; as in the gems of the Honeysuckles, Loniceræ; and the Violets, Violæ, &c. In the marginal cut, *e*. is a section of the unexpanded leaf of the Yellow Water Lily, Nuphar *lutea*.

3. The Revolute *(Revoluta)*, in which the lateral margins are rolled outwards; as in the gems of Rosmary, Rosmarinus *officinalis;* and of the Primrose genus, Primula, &c. In the marginal cut, *f*. is a section of the unexpanded leaf of Patience Dock, Rumex *patientia*.


4. The Circinal *(Circinata)*, in which the leaf is rolled from the apex to the base, as in the Ferns, Filices; the divisions of the leaf, as represented at *a. a.*, in the marginal cut, being rolled upon the mid-rib, which is also rolled from *b*. to *c*. carrying the divisions in its turns.

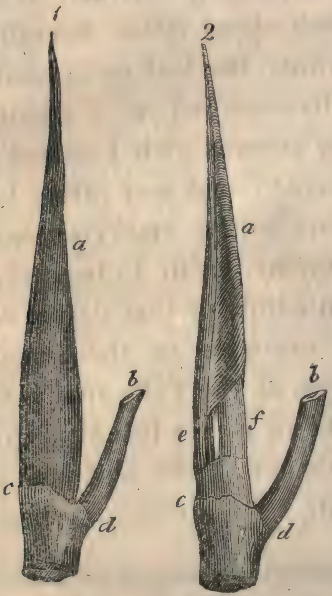
5. The Turned down *(Reclinata)*, in which the leaf hangs down and is wrapt round the footstalk, as in the buds of officinal Wolfsbane, Aconitum *neomontanum;* the genus Anemone, &c. In the marginal cut representing an unexpanded leaf of Duck's-foot, Podophyllum *peltatum*, *a. a.* shows the leaf wrapped round the footstalk *b. c.*




As the gems open, the leaves gradually unfold themselves, and assume their natural forms; but the opening of the bud does not, in every instance, immediately set free the leaves; for, in some gems, each leaf is separately enclosed in a membranous cover, which opens either laterally or at the apex, and permits the leaf to expand. This covering is generally regarded as a stipule *(stipula);* but it scarcely accords with Linnæus's definition of that appendage* ; and may rather be considered as a protection to the embryon leaf, until it has attained sufficient vigour to bear the stimulus of light, and to admit of that degree of perspiration, which its exposure to the atmosphere occasions. The gem of the Tulip tree, Liriodendron *Tulipifera*, affords a very beautiful example of this form of foliation. The leaf before expanding is conduplicate and arched, or bent

* "*Stipula* est squama, quæ basi petiolorum aut pedunculorum enascentium utrinque adstat." *Phil. Bot.* § 84.


down as represented at *a.* in the marginal cut; and the stipules, as they are termed, which are flat foliaceous plates (see *b.* which is one of them separated to show its form and vessels), form a bivalve case for it, containing at the same time all the younger leaves, each arched and enclosed in a similar manner. As soon as the leaf is capable of bearing the exposure, the two plates of the case separate, bending down as at *c. c.* and in a short time drop off; meanwhile the footstalk of the leaf becomes




straight and the disk is spread out to the light and air. In some instances this covering is univalvular and separates at the base, at the same time that it opens laterally, as exemplified in the Magnolias; and very elegantly in the Elastic-gum tree, Ficus *elastica;* the sheath of which (see fig. 1. *a.* in the marginal cut) is of a deep red colour,

thick, opaque, and covering the whole of the terminal shoot above the insertion *d.* of the last evolved leaf, the footstalk of which *b.* is purposely left in the figure: in fig. 2, the sheath is removed to display the leaf *a.* seated on its footstalk *e.* and wrapped round the sheath of the next expected leaf. In other instances this sheath is thin, semi-transparent, and filled with a gelatinous matter, which involves the young leaf; as exemplified in the Dock tribe, Rumex. These sheaths or utricular coverings cannot be regarded as hybernacula, as they are present in every season of the year; but, inasmuch as they preserve the young leaf from the stimulus of light and the effects of moisture, they bear a close analogy to the hybernacular scales. Their chief use, however, is to restrain the perspiration of the young leaf, till such time as its vessels are sufficiently perfect to supply by absorption the exhaustion of moisture which that function necessarily occasions.

The origin of the gem has been already sufficiently investigated (p. 383-406). It is evidently nourished during the summer by the leaf, which is, perhaps, to the embryo in the gem, what the flower is to the fruit *; but when the leaf falls, the gem is left to its own resources; and scarcely any visible change occurs in its aspect or its magnitude

* "La feuille est au bourgeon ce que la fleur est au fruit "et à la graine." *Essais sur la Vég.* par A. Aubert du Petit-Thouars, p. 145.

until the following spring. During this torpidity, which is maintained throughout the winter, the scales are supposed to preserve the enclosed embryo from the effect of cold; but if we reflect on the insufficiency of so feeble a guard, and further consider the great degree of cold which a seed can withstand without losing its vitality, we shall be able to appreciate justly the value of this opinion. The fact is, the vitality possessed by the embryo in the gem, like that it enjoys in the seed, is not susceptible of the stimulus of heat under a certain degree of temperature; and until it receives this, in combination with circumstances otherwise favourable for vegetation, no change of organization is produced in it, and the vital principle remains unaffected, even in very low temperatures. Nor is this wonderful when we consider that a caterpillar may be frozen, and yet live after it has been thawed. But if the gems remained uncovered during the long period which intervenes between their formation and evolution, they would run great hazards from the effect of moisture, and from the depredations of insects, against which the scales and the varnishes which cover them are excellent safeguards. We, besides, know that light is unfavourable to the evolution of the embryo in the seed, and may we not conclude from analogy, that this is the case also to the young branch in the gem?

When the spring returns, and the temperature

of the atmosphere has arrived at that point which the excitability of the gem demands for arousing its vital energy into activity, the outer scales being no longer useful, drop off; but the inner ones remain and assume the functions of leaves, until the real leaves are fully expanded. All the gems on a tree, however, do not open at the same time, for the current of fluid in the sap vessels communicating with the terminal gems being more direct than that which supplies the lateral gems, the former always open sooner than the latter. Flower gems almost always open before leaf gems on the same tree; but flower gems which are at a distance from leaf gems, generally fall without producing fruit; and perhaps they possess altogether less individuality than leaf gems, yet flower gems live and flourish when they are detached and then budded near a leaf gem on the same or on another stock. We are now treating, however, of the conservative organs only of plants; I shall, therefore, at present, not enter upon the examination of the flower gem; but pass on to treat the contents of the leaf gem; or leaves and their appendages.

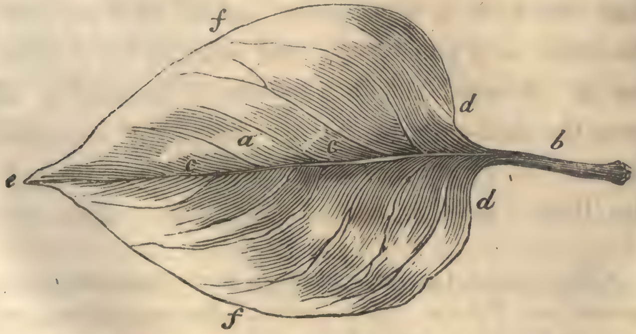
Leaves are organs of essential importance to the vegetable. They are, also, objects of great delight and interest, whether we examine them individually as the clothing of a single plant, or collectively as producing the lively freshness of the

verdant vale, and the massive luxuriance of the darkened forest. The most beautiful flower loses half its charms when it is displayed on a naked stem; the miserable hovel becomes picturesque when spread over with the foliage of the Vine; the ruins of former magnificence acquire more reverence, and command a double share of our respect, when seen through the tracery of the Ivy; and the horrors of the frowning rock are softened into beauty when mantled with pendent creepers or with Alpine shrubs. Leaves are still more important when we regard them as affording food to man and the rest of the animal creation; and supplying medicinal agents to relieve their sufferings in disease. Notwithstanding, however, the interest which they thus excite; and our familiarity with leaves, as objects of sight, from our earliest years, it is impossible to form an unexceptionable definition of the leaf. This difficulty arises from the great diversity of figure, substance, surface, and colour which it assumes in different plants. If we cannot, therefore, define it accurately from its external characters, we must have recourse to its functions; and perhaps the following is the least exceptionable definition we can offer: —*The leaf is a temporary organ of plants, which performs nearly the same function in the economy of vegetable life as the lungs perform in that of animal life:* or, in fewer words, *leaves are the*

*respiratory organs of plants**. It may be objected to this definition, that some plants, as for example the Dodder, Cuscuta *Europea*, the Stapelias, and many of the Cactus tribe, are devoid of leaves; but in these instances, and in all aphyllous plants, the surface of the stem performs the function of the leaves.

The diversity of character which leaves display is taken advantage of by systematic Botanists for determining species, and consequently every circumstance connected with that diversity,—as *form, substance, position, attachment,* and *direction* should be made familiar to the student; as well as the more intimate or internal structure of the leaf itself. In our examination, therefore, as in the case of stems, I shall first demonstrate the external characters of leaves, and then investigate their anatomy or internal structure.

Let us take any leaf from among those now scattered before us; this for instance of the Lilac.




* "Folia transpirant et adtrahunt (uti pulmones in anima-"libus) umbramque præbent." *Phil. Bot.* 81.

We find that it consists of two parts; the one, *a.* (see the figure) thin and expanded, and which in common language is named the leaf *(folium)*; the other *b.* long, equally thick as broad, and stalk-like, which is denominated the footstalk or petiole *(petiolus)*. The footstalk and the expansion, however, constitute but one organ or proper leaf, the footstalk being merely a prolongation of the *mid-rib c.c.* which in this leaf divides the expansion into two equal portions. This is further proved by the fact, that the expansion cannot be separated from the footstalk without tearing or cutting; and that in autumn, when a leaf withers, both parts fall together, the whole leaf separating, on the slightest touch, at the point where the foot-stalk is attached to the branch*. But many of the leaves before us have no prolongation of the mid-rib, thence we conclude that the petiole is not universal. Continuing our examination, we observe that the two surfaces of this leaf are not alike; that one is of a deep green colour and smooth; the other is a pale green and marked by a number of elevated ridges *(costulæ)*, branching off from the mid-rib: the deeper green and smoother surface is always turned upwards or towards the light, and is named the *upper disk (pa-*

* The error of Linnæus's definition of the footstalk is very apparent:—" *Petiolus*, trunci species, adnectens folium, nec " fructificationem." *Phil. Bot.* § 82. F.

*gina superior)*, or face of the leaf; the latter, which has of course the opposite direction, is termed the *under disk (pagina inferior)*, or back of the leaf: but, as I remarked with respect to the footstalk, these distinctions of surface are not universal, for we meet with some leaves which stand vertically on the branches and have both surfaces alike*. That part of the leaf *d. d.*, which is next to the footstalk or to the point of attachment, is always considered as the *base;* and the part *e.*, which is directly opposite, the apex; whatever may be the shape of the leaf. The line *e. f. d. d. f. e.* forming the contour of the leaf, is named the *margin*. The angle which the leaf or its footstalk forms at its point of attachment with the stem, or the branch, is termed its *axilla*.

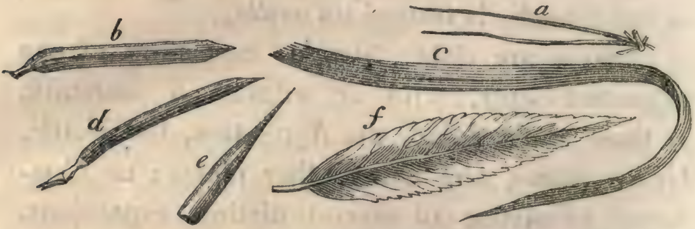
Leaves are either *Simple*, consisting of one expansion only, with or without a footstalk, as those of the Lilac, the Apple tree, the Nettle, Urtica *dioica*, and many other plants; or *Compound*, consisting of several distinct expansions, with or without distinct footstalks united together on one common footstalk, as those of

* Mirbel considers these as transformed footstalks. He remarks, speaking of the *Acaciæ* of New Holland, "A mésure "que les folioles disparaissent, les pétioles changent visible- "ment de forme et de structure. La plupart s'élargissent vers "les deux bouts, à la manière d'un fer de lance." *Elémens de Phys. vég.* 1. 149.

Buck-bean, Menyanthes *trifoliata*, of Horse Chesnut, Æsculus, the Vetch tribe, Vicia, &c.

A. SIMPLE LEAVES *(Folia simplicia)* differ in respect of *general figure; form or solid configuration; apex; base; margin; surface;* and *substance.*

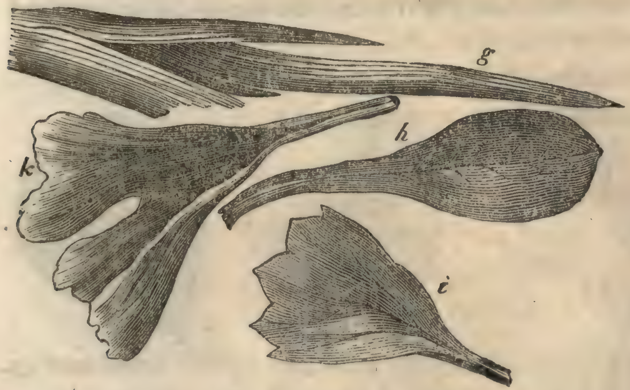
*a.* The *general figure* or superficial aspect of a leaf is derived from the line which circumscribes its flat surface, or which is described by its margin. In demonstrating the diversities which it displays, I shall begin with the simplest and pass progressively to the more complex. A leaf is termed Capillary *(folium capillare), a.*, when it is long, fine, and flexible, resembling a hair. Linear *(lineare), b.*, when it is long, about a geome-




trical line in breadth, and the sides parallel, or is the same breadth near the apex as at the base. Gramineous or riband-like *(fasciarium), c.*, when it resembles the linear, with which it is sometimes confounded, but from which it differs in being broader and not parallel towards the apex. Needle-shaped *(acerosum *), d.*, when, resembling

* "*Acerosum* est lineare persistens: ut in *Pino, Abiete,* "*Junipero, Taxo.*" *Phil. Bot.* Notwithstanding this high au-

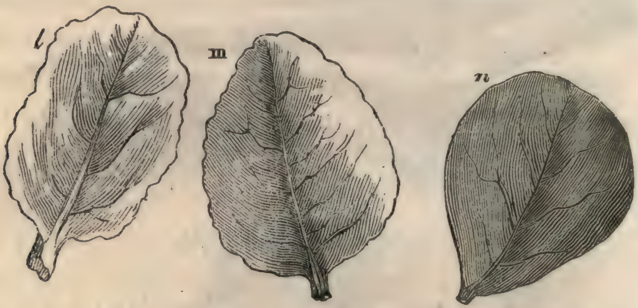
the linear, it is rigid and acute. Awl-shaped *(subulatum)*, *e.*, when it is thick at the base and gradually attenuated to a sharp point. Lanceolate *(lanceolatum)*, *f.*, when it is four or five times longer than it is broad, and tapers towards both the base and apex. Sword-shaped *(ensiforme)*, *g.*, when it is long, tapering to a point, very thin on both edges, and slightly curved. Spatulate *(spathulatum)*, *h.*, when round at the apex it gradually tapers towards the base. Wedge-shaped *(cuneiforme vel cuneatum)*, *i.*, when broad



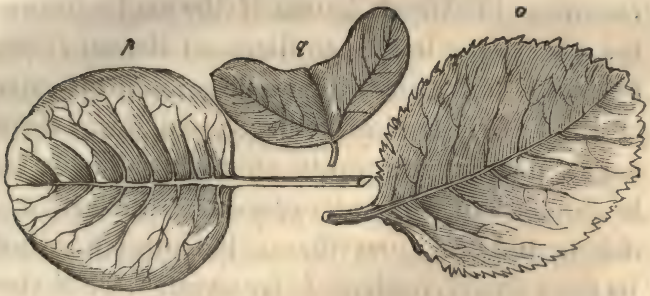

and abrupt at the apex it tapers towards the base. Fan-shaped *(flabelliforme)*, *k.*, when it resembles the wedge-shaped leaf in the base, but is more dilated and rounded at the apex. Ob-

thority, neither the leaves of the Yew nor of Juniper can be regarded as needle-shaped. Linnæus adds another circumstance connected with the needle-shaped leaf, more correct, "plerumque basi articulatione ramo inserta." *Phil. Bot.* § 277.

long *(oblongum)*, when the length exceeds the breadth at least more than three times, with the ends generally rounded: but the base and apex may be variously defined; "and this term," as Sir J. E. Smith justly remarks, "is used with great "latitude." *Oval* or *elliptical (ovale vel ellipticum), l.*, when it is twice as long as it is broad, and is nearly equally rounded at both extremities. Ovate *(ovatum), m.*, when the length is greater than the breadth, with both extremities rounded, but the base much broader than the apex. Obovate *(obovatum), n.*, when it has the ovate shape reversed;




and is consequently attached by the narrower extremity. Roundish *(subrotundum), o.*, when it approaches to the circular figure. Circular *(orbiculare), p.*, when its length and breadth are equal and the circumference is a circular line. Crescent-shaped *(lunulatum s. semilunatum), q.*, when it is curved, as the name implies, like a crescent: whether the footstalk be inserted into the concave or the convex edge of the crescent. Angled *(angu-*




*latum)*, when the circumference has considerable projections, which are not lobular: and the leaf is termed three-angled *(triangulatum)*, *r.*, four-angled *(quadrangulatum)*, and five-angled *(quinquangulatum)*, *s.*, as the angles are either three, or four, or five. If the angles be obscure, the leaf is said to be repand *(repandum)*. It is trowel-shaped *(deltoides*)*, *t.*, when it has three angles, or


* " Deltoides, rhombeum est ex quatuor angulis, e quibus " laterales minus a basi distant quam reliqui." *Phil. Bot.* Sir J. E. Smith states that " a wrong figure is quoted for this in " *Philosophia Botanica*, which has caused much confusion." *Introduc.* p. 155. He might have added, that the whole description is erroneous.

resembles the Greek $\Delta$, one of the angles forming the apex of the leaf: and diamond-shaped *(rhomboideum), u.*, when the lines describing the edges of the leaf, instead of being curved, form obtuse angles pointing outwards on each side. A leaf is fiddle-shaped *(pandurœforme), v.*, when it is oblong and has a curvilinear indentation in both its sides: and lyre-shaped *(lyratum)*, *, when there

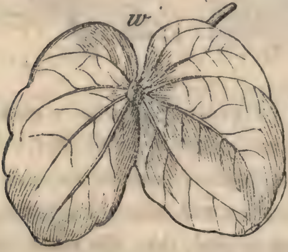
u

*

v

is one large circular or elliptical lobe towards the apex, and several small lateral lobes towards the base. It is termed lobed *(lobatum)*, when it is deeply divided into rounded segments; and is, therefore, said to be two-lobed *(bilobum), w.;* three-lobed *(trilobum), x.;* four-lobed *(quadrilo-*

w



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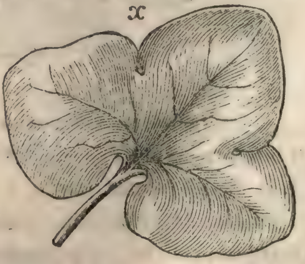

*bum)*, &c. according to the number of the lobes.

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It is arrow-shaped *(sagittatum)*, *y*., when the disk is triangular, and the sides are produced downwards into two pointed lobes, like a barbed arrow: and halberd-shaped *(hastatum)*, *z*. 1., when the sides are produced into two lateral spreading points or lobes near the base. Sometimes the lateral lobes are distinct, as represented at *z*. 2.


A leaf is heart-shaped *(cordatum)*, *a*., when it is hollowed at the base into two lobes and pointed at the apex, so that the leaf has somewhat the appearance of the heart on a card. When the apex, instead of being directly opposite to the base, is thrown off at one side, the leaf is said to be *oblique cordatum*, β, as beautifully illustrated in *Begonia*. Kidney-shaped *(reni-*

*forme)*, *y.*, when the apex is broad and rounded, and the base deeply hollowed out. A leaf is termed palmated *(palmatum)*, δ, when it is cleft into oblong or finger-like lobes, not, however, extending to the base; but leaving an entire flat space, which has been likened to the palm of the hand. Laciniated or incised *(laciniatum seu sectum)*, ε, when it is cut into numerous irregular


divisions, which are termed *segments.* Parted *(partitum)*, *i.*, when the clefts reach nearly to the base: and according to the number of these, the leaf is said to be *bipartitum, tripartitum, quadripartitum, quinquepartitum, multipartitum.* It is said to be cloven *(fissum)*, when the margins of the segments are nearly straight lines: and according to the number of the clefts the leaf is termed *bifidum, trifidum, multifidum, x.* (page 491), &c. Runcinate *(runcinatum)*, λ, signifies that the expansion is deeply cut into many transverse acute-angled segments, the points of which tend towards the base of the leaf. When the segments are deeper. and more regular and distant from

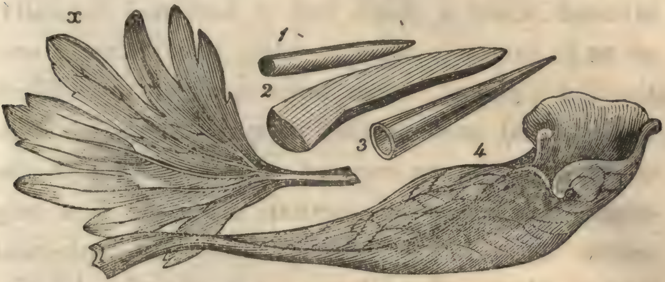
each other, the figure of the leaf is termed pinnatifid *(pinnatifidum)*, $\mu$; and pectinate *(pectinatum)*, $\nu$, when the segments are very narrow, linear, and parallel like the teeth of a comb.


These terms are frequently combined to express modifications of two or more of the forms they imply conjoined in one leaf. Thus you will find in the descriptions of leaves, in systematic works, such terms as *ovato-lanceolatum*, *cordato-lanceolatum*, *hastato-lanceolatum*, *cordato-ovatum*, *lineari-lanceolatum*, *cordato-sagittatum*, *sagittato-ovatum*, *lanceolato-ellipticum*, *subrotundo-cordatum*, &c. the meaning of which can be accurately acquired by practice only in the examination of plants. The three last-mentioned terms, I ought to notice, involve a contradiction; or, at least, are too nice for practical purposes; and consequently we find, that several of the best systematic Botanists have confounded and misapplied them. The terms *incisum* and *dissectum* are merely modifications of *laciniatum*. I may take this opportunity of remarking that the

terms angled and lobed are, also, not unfrequently misapplied, although the distinction is perfectly obvious: thus, each segment of an angled leaf has the margins, which meet to form the angle, straight or nearly so; whereas in a lobed leaf the margins are always curved, so as to give the lobes a rounded appearance, whether their apexes be obtuse or pointed. The importance of accuracy in the application of terms significant of the forms of leaves, will be fully seen when I come to treat of the classification of plants.

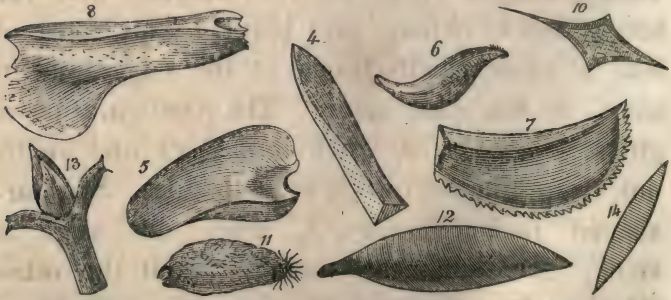
*b.* The *solid configuration of a leaf* is taken from its real form, including length, breadth, and thickness; determined by transverse and longitudinal sections. It is termed Cylindrical *(teres, cylindrica)*, 1, when a transverse section, made any where throughout the greater part of the length of the leaf, is circular. If the diameter be very small, so that the leaf is as fine as a hair, the configuration is termed *capillacea,* the distinction of which from capillary, consists in the form of the *capillaceous* leaf being exactly that of a hair, whereas the *capillary* is only as small as a hair:—Semicylindrical *(semicylindracea)*, 2, when one side of a leaf is flat and the other convex:—Tubular *(tubulosa)*, 3, when the greater portion of the leaf is cylindrical, or nearly so, tapering to a point, and hollow within. Sometimes the hollow appears as if it

were formed by the two sides of the leaf being compressed together, but separated near the midrib, so that one part of the leaf is flat and another tubular, as beautifully exemplified in the genus *Sarracenea*, 4.—The configuration is four-edged *(tetragona)*, when there are four longitudinal sides, and consequently four corners: but if there be three sides only, as in Mesembryanthemum *aureum*, the configuration is termed




*trigona*, 4 (see page 492); Linnæus uses *triquetrum* to express an awl-shaped leaf, which has three flat sides; but the term is superfluous. Tongue-shaped *(lingulata)*, 5, implies that the leaf is thick, oblong, and blunt. This form of leaf is often cartilaginous at the edges, as in some of the Aloe tribe. The configuration is gibbous *(gibba)*, 6, when it is thick and swells out, or is humped on one or both sides. Symitar-shaped *(acinaciformis)*, 7, when one edge is thick, flat, and nearly straight, and the other thin, sharp, and curved like a symitar. Hatchet-shaped *(dolabriformis)*, 8, when it resembles the

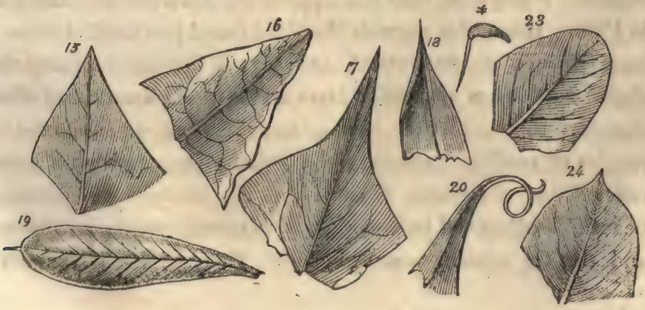
former, but has the keel or compressed part more abruptly prominent, and the base nearly cylindrical. Sir J. E. Smith remarks, that "these two "last terms might well be spared, as they seem con"trived only for two plants," but this is supposing that the whole vegetable world is already known, which is very far from being the case. The same leaves are examples, also, of the two next terms of configuration: the Compressed *(compressa)*, which is used when a thick leaf is flattened laterally, so as to make it thicker than it is broad; and the flat *(plana)*, when both surfaces of a thick leaf are flat and parallel to each other. A two-edged leaf *(folium anceps)*, 10, displays both the edges, in a transverse section, produced to a very acute angle. The configuration is spherical *(sphæroidea)*, when it approaches to the globular form: Ovoide *(ovoidea)*, 11, when it somewhat resembles that of an egg: Coccoon-shaped *(fusina)*, 12, when it is cylindrical in the middle



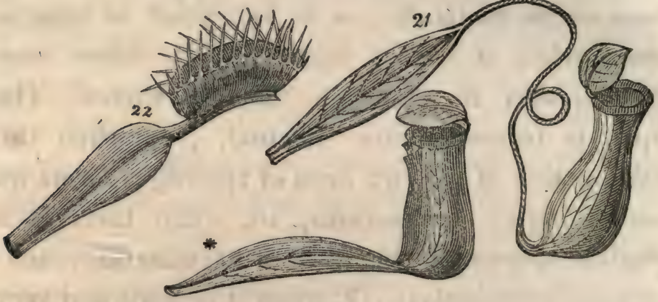

and tapers to a point at each end: Club-shaped *(clavata)*, when it is round and stem-like, with a

thick, blunt apex: Hooked *(uncinata)*, 13, when it is curved so as to resemble, in some degree, a hook: Lenticular *(lenticularis)*, when it is flat, roundish, and convex on both surfaces, and a transverse section of the leaf has the appearance represented at 14, in the cut.

*c.* The *apex* of a leaf, as has already been described, is that part which is opposed to the base or the footstalk; or to the point of attachment when it has no footstalk. It differs very considerably in shape in different leaves. The apex is termed acute *(acutus)*, 15, when the conjunction of the two lines of the edges forms an acute angle: *acutiusculus*, 16, when there is a slighter degree of this kind of termination: acuminate *(acuminatus)*, 17, when it is long and very tapering: spine-pointed *(cuspidatus)*, 18, when it runs out gradually into a small, awl-shaped, rigid spine; and mucronate *(mucronatus)*, 19, when it is rounded with an herbaceous spine standing on it. The apex is awned *(aristatus)*,*, when it is



terminated by a long rigid spine, which does not appear as a continuation of the leaf: cirrose *(cirrosus, circinatus)*, 20, when it is produced into a kind of tendril; and this is in a few instances "furnished with an additional organ for some particular purpose not essential to a leaf ‡." Thus, in one species of the genus Nepenthes†, 21, the




‡ *Smith's Introduction*, p. 173.

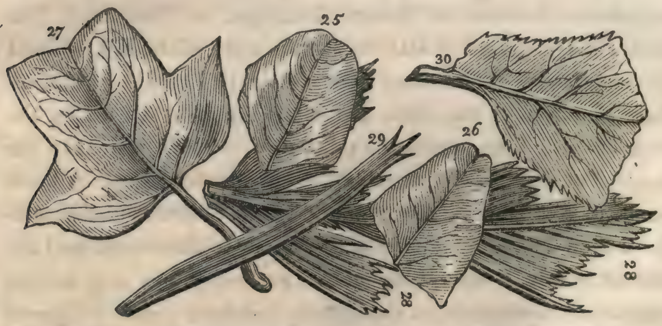
† This singular family of plants was first noticed by Hieronymus Benzoni, an Italian, who visited India about the middle of the sixteenth century (1542—1556); and was described by him in a work entitled, "Nova novi Orbis Historia," Genevæ, 1578. One species of it, the *Phyllamphora (Lin.)*, was afterwards fully described and figured in the Herbarium Amboinense of Rumphius, who was appointed Governor of Amboyna in 1706. Rumphius regards the fluid found in the pitcher as a secretion of the plant itself, and says it increases during the night; that it has a sweetish taste and attracts worms and other insects into the pitcher; who, however, all die, except a species of squilla, "squilla gibba," that seems to prey upon the carcasses of the others. He describes the pitcher itself as being beautifully coloured in the inside with purple streaks and spots; and the lid opening and shutting. This species is found in

apex of each leaf terminates in a long rigid thread, a continuation of the midrib, bearing a small covered pitcher, which is generally found nearly full of water: in another species this pitcher is sessile, *; and, in Dionæa *muscipula*, the appendage is composed of a pair of toothed lobes, 22, which are irritable; and which close together and imprison insects that alight upon them †. The apex is obtuse *(obtusus)*, 23, (p. 493), when it forms the segment of a circle or is rounded. The rounded apex of a solid leaf, when a little thick-

Amboyna growing in dry waste places; and also in Ceylon; but I suspect that the Ceylon plant is a variety, if not a distinct species, for the pitcher is not contracted at the neck, as in Rumphius's figure, and it is found growing only in moist valleys and on the banks of rivers. At this time (August 1821), there are several plants of Nepenthes *distillatoria* vegetating in pots, in the magnificent hothouse of Messrs. Loddiges, at Hackney. The pitcher in this species is attached to the apex of the leaf, without the medium of the twisted wire, which is found in *Phyllamphora;* and there are, also, two leafy appendages running the whole length of the pitcher, on that side of it which is next to the plant. The lid exactly resembles that of *Phyllamphora.* A more beautiful vegetable pitcher is found in the Cephalotus *follicularis*, a New Holland marsh plant, which was discovered and described by Mr. Robert Brown, to whose exertions and talents Botanical science is most extensively indebted; and is figured in the atlas of Capt. Flinders's voyage; but, as it is not appended to the leaf, I shall describe it among the general appendages.

† The cause of this vegetable phenomenon shall be afterwards investigated.

ened, but not sufficiently so as to render it clubbed, is termed *incrassatus*. If a small point project from the middle of the obtuse apex, the leaf is said to be *obtusum cum acumine*, 24 (p. 493). The apex is termed retuse *(retusus)*, 25, when it is obtuse, with a broad shallow notch in the middle: emarginate *(emarginatus)*, 26, when the notch is sharper, or nearly triangular: truncated *(truncatus)*, 27, when it appears as if cut across in a straight line; as beautifully exemplified in the leaf of Liriodendrum *tulipifera*. It is jagged *(præmorsus)*, 28, when it appears as if gnawed off, and the cross lines describe several irregular points. Ex. Caryota *urens* (28); and tridentate *(tridentatus)*, 29, when it forms three teeth.




*d.* The differences in the *bases* of leaves depend on the general superficial configuration; I must, therefore, refer you to what has been said on that subject, and notice here one circumstance only,

connected with the base, which has not already been described. When the two halves of the expansion are of different lengths, this is observable chiefly at the base, and the leaf is said to be unequal or oblique *(basi inæquale)*, 30, (page 496).

*e.* The *Margin* of a leaf may be either entire, indented, bordered, or rolled.

* *Entire.*

An entire leaf *(folium integerrimum)* has the line of the margin uninterrupted, or free from every kind of incision or indentation. Sir J. E. Smith properly remarks that this term refers solely to "the margin of a leaf; whereas *in-*" *tegrum* respects its whole shape, and has no-" thing to do with the margin†." I may add, it is used in contradistinction to *compositum.*

** *Indented.*

A leaf is termed sinuated *(sinuatum)*, 31, (page 498), when the margin is cut into roundish scollops, as in the Oak, Quercus *robur;* but when the notches or scollops are very irregular, as if formed by the gnawing of some insects, the margin is then said to be gnawed *(erosus)*, 32. It is termed toothed *(dentatus)*, 33, when it displays pointed marginal projections of the expansion, with interstices between them; and the following terms are employed to express the character of the margin as far as re-

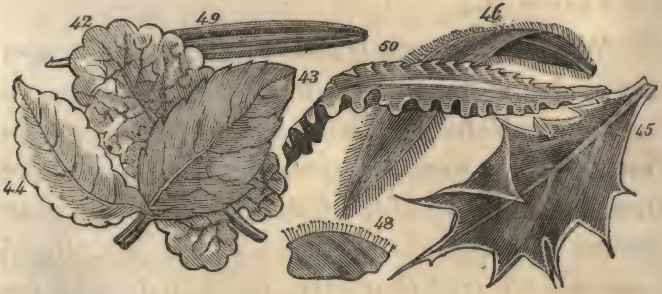
† *Introd. to Phys. and Syst. Bot.* p. 161.

gards its denticulations: equally toothed *(æqualiter dentatus)*, 34; unequally toothed *(inæqualiter dentatus)*, 35; deeply toothed *(profunde dentatus)*; obscurely toothed *(obsolete dentatus)*, 36. If the denticulations themselves be again dentated, then the margin is termed doubly dentate *(duplicato-dentatus)*, 37.

The margin is denominated serrated *(serratus)*, 38, when the teeth are sharp, and lie as it were upon each other, as in a saw, all pointing towards the apex of the leaf. The nature of the serratures is distinguished by the following terms applied to the margin: equally serrated *(æqualiter serratus)*; unequally serrated *(inæqualiter serratus)*; sharply serrated *(argute serratus)*; deeply serrated *(profunde serratus)*, 39; and doubly serrated *(duplicato-serratus)*, 40. When the serratures are minute, or not distinct, the margin is termed *serrulatus*, 41.

Crenated *(crenatus)*, 42, implies that the indentations of the margin are blunt and rounded, and do not incline to either extremity of the leaf. The crenatures themselves may be crenated, in which case the margin is termed doubly crenated *(duplicato-crenatus)*; or they may be of a doubtful form, being neither completely rounded nor yet pointed, in which case it is termed *dentato-crenatus*, 43; and crenulated *(crenulatus)*, 44, if they are very shallow and at the same time perfect.

When the marginal denticulations, whatever form they assume, are terminated with sharp, rigid spines, the margin is termed spinous *(spinosus)*, 45; and as a comparative term, a leaf is said to be unarmed *(inerme)*, when it occurs in a species or a variety belonging to a tribe of plants, which has for the most part spinous-leaved species.




*** *Bordered.*

When the substance of the margin of a leaf differs from that of the expansion, the leaf is considered as *bordered;* and according to the charac-

ter of the border, the margin receives different appellations. Thus it is termed cartilaginous *(cartilagineus)*, when it is firmer than the disk and somewhat elastic. This cartilage is generally whitish, yellowish, pinkish, or some other colour, but is seldom green. It is termed horny *(corneus)*, when it resembles the cartilaginous, but is harder and less elastic: ciliated *(ciliatus)*, 46, when beset with soft parallel hairs, not closely set together; but if the hairs be stiff and like bristles, it is then said to be *aculeato-ciliatus*. (See fig. 1. Plate 4).

If the margin be studded with small granular, either opaque or semitransparent bodies, exuding some kind of fluid, it is termed glandular *(glandulosus)*; but, if these glands be supported on hairs, *glanduloso-ciliatus*, 48.

**** *Rolled.*

When the margin is rolled backwards, or upon the under surface of the leaf, it is said to be revolute *(revolutus)*, 49; when forwards, involute *(involutus)*. In some instances the margin, comprehending a portion of the disk of the leaf, is so much more expanded than the rest of the disk, that it assumes a waved character, or is undulated *(undulatus)*, 50; and when it is still more expanded, so that the margin is variously curled and twisted, it is termed curled *(crispus)*. These appearances occur in leaves, which have very different kinds of margins in other respects.

*f.* The *surface* of a leaf comprehends both the upper and the under disks. In general, the upper disk is smoother than the under disk; for, although the vascular fasciculi can be traced in the form of white or coloured lines on the upper, yet, they very rarely produce those elevated ridges which mark their course on the under disk. In treating of the different characters that distinguish the surfaces of leaves, the upper disk only is alluded to. It is necessary to state that the greater number of the following terms are equally applicable to the surface of the stem as to that of the leaf, when the contrary is not expressed.

The surface of a leaf which exhibits no inequalities is said to be flat *(plana vel lævis)*; if there be no hairs nor spines, it is smooth *(glabra, nuda)*; and if no fasciculi of vessels be apparent on it, veinless *(avenia)*. If it be smooth and shined, it is termed polished *(nitida)*; and lucid *(lucida)*, if it be so considerable as to present the appearance of being varnished. If the upper surface be convex and the under concave, the leaf is termed convex *(convexum)*; and the opposite of this state, concave *(concavum)*. Both these states are the consequence of a tightness of the margin. When an oblong or a linear leaf is longitudinally hollowed, and a transverse section of it is a semicircle, the surface is said to be channelled *(canaliculata)*, 52, (p. 503); but when the transverse

section is angular, and the midrib on the under surface resembles the keel of a boat, it is keeled *(carinata)*, 53. When, instead of one longitudinal hollow, there are several linear depressions, the surface is said to be furrowed *(sulcata)*, 54; and streaked *(striata)*, if the depressions be superficial, very narrow, and in parallel lines. If the surface be depressed in the centre, and the leaf is peltate, it is said to be navel-like *(umbilicata)*, 55: but if it rises and sinks alternately, in straight angular furrows, like the folds of a fan, it is termed folded *(plicata)*; and waved *(undulata)* if in undulations commencing from the midrib. When the inequalities proceed from the portions of the expansion between the network of the vascular fasciculi being fuller than is requisite to fill the vacant spaces of the meshes, and rising upwards, the surface is wrinkled *(rugosa)*, 56; and blistered *(bullata)*, when these elevations are still more considerable; but when, on the contrary, the fulness between the vascular fasciculi produces depressions, the surface is said to be pitted *(lacunosa vel favosa)*.

When a leaf is covered with small hard tubercles, which are more easily distinguished by the finger than the eye, the surface is said to be scabrous *(scabra)*: it is rough *(aspera)* when these are more visible; warty *(verrucosa)*, 57, when they are still larger and more solid; and pustular,

or vesicular *(papillosa),* when they are evidently elevations of the cuticle filled with aqueous fluid, as in the Ice plant, Mesembryanthemum *crystallinum.* If the surface of a leaf be studded with short herbaceous spines, it is termed muricated *(muricata);* when these have stiff points, it is prickly *(echinata);* and aculeated *(aculeata),* when, instead of being herbaceous, the spines are hard and pungent. The surface is termed hispid *(hispida),* when it is beset with short stiff hairs; when these are longer, and consequently less rigid, it is hirsute *(hirsuta);* bristly *(setosa),* 59, if they stand


singly and resemble bristles; strigose *(strigosa),* if they are firm, and stand upon small prominences, or papillæ*: and bearded *(barbata),* when they are rather long and crowded together. Soft hairs are generally termed pubescence, and the surface of the leaf receives various appellations from the

* "Strigæ arcent setis rigidis animalcula et linguas. *Cac-* "*tus, Malpighia, Hibiscus, Rubus.*" *Phil. Bot.* § 163.

character of this description of covering. Thus it is hairy *(pilosa)*, when the hairs are soft, distinct, somewhat long, and bent; shaggy or velvety *(villosa)*, when they are soft, nearly erect, and parallel; silky *(sericea)*, when they are soft, and lie thick and flat on the surface, giving it a satin-like lustre; downy *(tomentosa*)*, when they are very soft and matted together, so that the individual hairs are not distinguishable; woolly *(lanata†)*, 60, (page 503), when they are also matted together, but yet individually distinguishable; tufted *(floccosa)*, when they are soft and matted, and can be easily detached in small tufts; and starred *(stellata)*, when the hairs or the spines are radiated like stars. In some instances the stellated appearance proceeds from pedicillated tufts; which under the microscope appear like branched shrubs devoid of foliage. It is necessary to remark that differences of age, climate, soil, dryness and humidity, alter very considerably the pubescence of plants; some which are tomentose when young, become hispid, or smooth, when old; others which are naturally hairy, become quite smooth when cultivated; and others, which in their native climate are smooth, become hairy when removed. Sir J. E. Smith, nevertheless, in opposition to the

* "*Tomentum* servat plantas a ventis; gaudet sæpius colore incano." *Phil. Bot.* § 163.

† "*Lana* servat plantas ab æstu nimio." *Phil. Bot.* § 163.

maxim of Linnæus, "pubescentia ludicra est dif-"ferentia, cum cultura sæpius deponantur *," remarks that "the direction of the hairs or "bristles proves a very sure means of distinguish-"ing species, especially in the genus *Mentha*, the "hairs about whose calyx and flower-stalk point "differently in different species; and," he adds, "I have found it the only infallible distinction "between one Mint and another †."

The surface of a leaf may be furnished with visible glands. When these are elevated, or on pedicils, the surface is said to be glandular *(glandulosa)*; but, when they are not raised, they appear like punctures, which either penetrate the substance of the leaf, or are merely superficial and visible on one disk only. In either case the surface is said to be dotted *(punctata)*, 58, (page 503). Any glandular exudation, if considerable on a surface, gives a character and denomination to it: thus, if it be moist and tenacious, the surface is termed viscid *(viscida vel glutinosa)*; it is hoary *(pruinata vel incana)*, if the secretion be a dry, very fine, waxy powder of a bluish colour, devoid of gloss, and easily wiped off; and mealy *(farinosa)*, if it resemble a mealy powder.

The majority of leaves is green; and, as has been already mentioned, this colour is of a deeper

* *Phil. Bot.* § 272. † *Introd.* p. 228.

tone on the upper than on the under disk: but the green colour, from its being nearly universal, is not noticed in the description of a leaf, except as regards its depth or tone; thence, the comparative terms dirty *(sordidus)*; intense *(intensus)*; full *(saturatus)*; pale *(pallidus)*; and diluted *(dilutus)*. The colour is denominated olive *(olivaceus)* when it is green with a shade of brown; and sea-green *(glaucus)*, when it appears bluish, or as if formed from a mixture of blue and green. When other colours mingle with the green, the leaf is termed coloured *(coloratum)*; and the differences of the colouring receive a determinate designation: thus, when the coloured portions afford the semblance of decay or disease, the leaf is termed variegated *(variegatum)*; spotted or maculated *(maculatum)*, when the colour is dark and in spots or blotches; and zoned *(zonatum)*, when the colours are displayed in one or more curved lines. The term *discolor* is employed to denote that a leaf displays one colour on one surface, and another on the opposite surface, as in purple-leaved Spiderwort, Tradescantia *discolor*, two-coloured Begonia, Begonia *Evansiana*, &c.

The vessels of every leaf enter it by the petiole, or by the point of attachment, in fasciculi; which afterwards separate, and are spread in various ways through the substance of the leaf. These, when visible, form lines, which are very

prominent on the back or under surface of the leaf, and have been very improperly denominated *nerves* and *veins*; for nothing has yet been discovered in vegetables bearing any analogy to nerves; and as the fasciculi contain both conducting and returning vessels, they may be termed arteries with as much propriety as veins. But the terms, notwithstanding their absurdity, being in general use, require to be explained. The larger fasciculi are denominated *nervi* and *costæ*, and the smaller *venæ*, in whatever manner they are disposed throughout the leaf; but the terms *nervosum*, *costatum*, and *venosum*, imply distinct dispositions of the fasciculi.

A leaf is said to be nerved *(nervosum)* when the larger fasciculi run, in simple, slightly curved lines, from the base to the apex; and the leaf is named according to their number, among which the midrib is reckoned as one. Thus three-nerved *(trinervis)*, 61, (page 509), means that the leaf has one longitudinal fasciculus of vessels on each side of the midrib, taking its origin from the base; and five-nerved *(quinquenervis)*, that it has two longitudinal fasciculi on each side of the midrib, under the same circumstances. It is seven-nerved *(septemnervis)*, 62, when there are three fasciculi on each side; nine-nerved *(novemnervis)*, when there are four; and many-nerved *(multinervis)*, when the number on each side exceeds four. The

nervation is in some instances not regular; but one large fasciculus is given off on each side of the midrib, at the very base of the expansion, dividing and subdividing as it proceeds, as in the annual Sunflower, Helianthus *annuus;* in which case the leaf is said to be *basi-trinerve,* 63. The same leaf is also an example of the term *venoso-nervosum,* which is used by some authors to imply that the nerves pass into veins. If the lateral longitudinal fasciculi do not spring directly from the base, but so far above it, that part of the expansion of the leaf is below them, as in the leaf of the Cinnamon tree, *Laurus Cinnamomum,* 64, the terms employed are *triplinerve, quintuplinerve, multiplinerve.* In one example of the multiplinerved leaf, Hydrogeton *fenestralis**, 65, the longitudinal fasciculi are united by transverse bands, forming square meshes, which are perfectly void, like wire-work, giving that character which Botanists have termed fenestrated, or open *(fenestratum).* But when the longitudinal fasciculi, forming excurrent nerves, are united by transverse fasciculi, however elevated or strongly marked these may be, if the intermediate spaces be filled with the expansion, as in 66, the leaf receives no particular appellation.

Ribbed *(costatum),* is sometimes employed as

* This singular plant is an aquatic, a native of Madagascar.

the synonime of nerved, and is certainly the more proper term of the two; but it is, also, specifically used to imply that the veins proceed from the midrib in lines nearly straight towards the margin, and parallel to each other. In some instances the costæ are close together and scarcely elevated, as in the Banana, Musa *sapientium;* but in others they approach to the character of nerves, except that the angle they form with the midrib is less acute, 67, and they do not appear to be split off from the midrib as in the multiplinerved leaf.

Veined *(venosum)*, expresses merely that the fasciculi of vessels are so elevated or marked in their branching and sub-branching, as to form a kind of network over one or both surfaces of the leaf. When the surface is altogether free from any appearances of the vascular fasciculi, the leaves are said to be nerveless, or veinless *(enervia, avenia)*, 70.

In speaking of the *substance* of a leaf, as far as that can be determined from its external characters, we refer to the expansion only; for, although the substance of the petiole is often the same as the expansion, yet this state is neither constant nor essential. All leaves may be regarded as *herbaceous*; but the term is occasionally employed in a determinate sense to denote a soft, green, pliable leaf, the vascular fasciculi of which are as succulent, and scarcely firmer than the rest of the leaf; as exemplified in Spinage, Spinacia *oleracea*, the different species of Goose-foot, Chenopodeum, &c. A leaf is termed membranous *(membranaceum)*, when it is thin and pliable, the quantity of parenchymatous matter being so small that the cuticle of the one surface appears almost closely applied to the other; as in Broad-leaved Birthwort, Aristolochia sipho; Scented Bramble, Rubus *odoratus*; and most trees and shrubs: but this term does not imply that uniformity of substance which the appellation herba-

ceous denotes. The terms scariose *(scariosum)*, and chartaceous *(chartaceum, papyraceum)*, are given to varieties of the membranous leaf; the first implying that it is dry, or apparently sapless, and somewhat translucent; the second, that it resembles paper, as in Draco *terminalis*. Leathery *(coriaceum)* implies that the leaf is thick, tough, and elastic; as in the Mistletoe, Viscum *album*, Changeable Hydrangea, Hydrangea *hortensis*, &c.: and rigid *(rigidum)*, that it is hard, with little elasticity, as in Butcher's broom, Ruscus *aculeatus*, Scotch fir, Pinus *sylvestris*, &c. Fleshy *(carnosum)* denotes that the leaf is thick, and consists chiefly of a juicy but firm cellular parenchyma, as in Houseleek, Sempervivum *tectorum*; and succulent *(succulentum)*, that the pulp is laxer and more juicy, as in Mesembryanthemum *echinatum*, &c. Mirbel says the consistence of the fleshy leaf is that of the Apple; of the succulent that of the Plum *.

As all the characteristics of leaves, which I have yet described, relate to the expansion, they are consequently peculiar to simple leaves only, or to the individual leaflets of compound leaves. Before detailing those common to both descriptions of leaves, it is requisite to understand the pecu-

* *Elémens de Phys. vég.* iii. p. 642.

liarities connected with the petiole or footstalk; and, as naturally arising out of these, the circumstances which constitute the compound leaf, with its species and varieties. The description of these, therefore, shall form part of the subject of our next Lecture.

Before closing this Lecture, however, I may remark that, although the study of the terms which denote the peculiarities of formation in the vegetable body, be apparently the least amusing part of our subject, yet, it is not altogether devoid of interest, from the great variety which Nature displays in this part of the creation; and I can assure those who may think it tedious, that the readiness with which it enables us to describe plants in proper Botanical language, and to understand the descriptions of others, fully repays the labour of the acquirement. Like learning a language of any kind, its utility becomes evident only after its acquisition; but then the stores of knowledge to which it serves as the key, are opened with a facility which is not less gratifying, than their magnitude and richness are astonishing and their possession delightful.

# LECTURE X.

OF THE PETIOLE. COMPOUND LEAVES. THE SITUATION, POSITION, INSERTION, DIRECTION, MAGNITUDE, AND EXTENSION OF LEAVES. ANATOMY OF THE LEAF.

THE FOOTSTALK *(petiolus)* in every instance in which it is present, constitutes a part of the leaf. It is simple, in some instances, consisting of one piece only, as in all simple leaves; or it is compound *(compositus)*, consisting of one common stalk divided into several distinct parts. The common petiole is generally termed primary *(primarius)*; the immediate divisions of this secondary *(secundarii)*; the divisions of these ternary *(ternarii)*, and those which support the leaflets partial *(partiales seu proprii)*. The petiole further differs in form, in the nature of its appendages, its mode of insertion into the leaf, and its articulations.

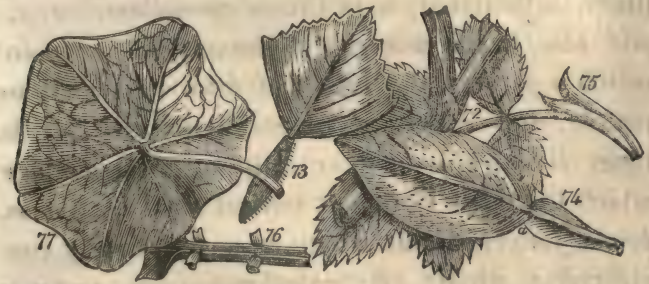
In respect of *form*, some of the terms employed in the description of the stem are applicable to the petiole. Thus it is said to be round *(teres)*; half-round *(semiteres)*; compressed *(compressus)*, &c. according to the figure of its transverse section. The compressed petiole occasionally assumes the

aspect and functions of a leaf, in leaves which suffer that change which is termed alienated *(alienatum)*; that is, when the compound leaves which are the first leaves of the plant, and natural to the tribe, afterwards give place to simple leaves, which are merely dilated petioles; as exemplified in several of the *Mimosas* from Botany Bay. De Candolle has named these intermediate forms *phyllodia*. The transition might be supposed to depend on the energy of the plant diminishing with its growth; for, when a plant of this kind is topped, the new leaves which are put forth display the same characters as the original foliage *; but, that this is not the case is evident, from the transition occurring constantly in New Holland, where the genus has every opportunity of following its natural habits. The majority of petioles are slightly furrowed on the upper side; but, when this is deep, it is particularly denoted by the term channelled *(canaliculatus)*, and when much dilated the petiole is said to be concave *(concavus)*. In the last-mentioned instance it sometimes partially embraces the stem

* I saw an illustration of this fact yesterday (25th September 1821), in the garden of Comtesse de Vandes, near Bayswater. An old plant of Acacia *falcata*, on which no pinnated leaves had been seen for several years, had been cut down and had put forth pinnated leaves, resembling in every respect, except in size, the first leaves of the plant. The second series of shoots, however, displayed falcated leaves only without any pinnæ.

*(amplexans)*, 72; or wraps completely around it, and then is termed sheathing *(vaginans)*, as in the Grasses. In some cases the petiole is inflated *(inflatus)*, and the plants in which this occurs being aquatic, it serves to float the leaf, as in Trapa *natans*, 73, &c.

The *appendages* of the petiole are not numerous. A footstalk is said to be winged *(alatus)*, when it has on each side of it a portion of the expansion, isolated from the rest, as in the Orange tribe, *Citrus*, 74. But there are leafy appendages of a distinct character, denominated stipules, which are yet to be described, in many instances attached to the petiole; as in the Rose tribe, *Rosa*, 75, in which case the petiole is termed stipuliferous *(stipuliferus)*. It is termed *glanduliferus*, 76, when one or more glands are




seated on it, as in the genus *Passiflora;* in the Castor-oil plant, Ricinus *communis*, &c.: and *floriferus* when it bears the flower, as in Elm-leaved Turnera, Turnera *ulmifolia*.

In respect to *insertion*, in the majority of in-

stances the petiole and the expansion are in the same plane; the insertion of the footstalk being at that portion of the margin of the expansion, which is regarded as the base of the leaf; but in some instances it is in the centre of the disk, and then the leaf is termed shieldlike *(peltatum)*, 77. The consideration of terms denoting the other insertions of the petiole is deferred until we examine the various insertions of the leaf, of which the footstalk is merely a part.

The term *articulation*, as applied to the petiole, is intended to denote that it consists of more than one piece, the pieces being generally united by a small intermediate portion, thicker and more spongy than the parts it unites, commonly of a different colour and capable of motion. The petiole of the simple leaf is rarely, although sometimes, articulated, as in Citrus *aurantium*, 74, *a.*; and, also, in the majority of Grasses, at that point which separates the real leaf from its sheathing petiole, and which is generally marked on the inner side by a small membranous appendage, which the elder Botanists termed *ligula* and *membrana foliorum*, but which is now properly considered a stipule. Articulation is very common in compound leaves. It occurs generally at the attachment of the partial to the common petiole, in such leaves as fold together their leaflets during the night; but, in some instances, there is an articulation, also, near the point where the

primary petiole springs from the branch, particularly in those plants which have irritable leaves, as Mimosa *sensitiva*, &c. At these secondary articulations the leaflets separate, and fall in autumn; sometimes before the common petiole falls, particularly when it is not articulated near its insertion. The term *inarticulatus* is employed comparatively, when leaves belonging to a tribe of plants, in which articulation is common, are deficient in this peculiarity.

The composition of the petiole necessarily implies that of the leaf; but a compound leaf does not necessarily imply the existence of either secondary, ternary, or partial petioles. The COMPOUND leaf may be thus defined:—a leaf which consists of seveal *distinct* expansions or leaflets, connected by *articulations* either directly or indirectly, and a common footstalk. This definition differs from that of the majority of Botanical writers, in regarding the connexion of the leaflets by articulations as the chief charasteristic of the compound leaf *; but I cannot consider any leaf

* Mr. Keith seems to be fully aware of this characteristic of compound leaves (see *Syst. of Phys. Bot.* vol. i. p. 54); and Bulliard thus defines the compound leaf: "La feuille composée "a une ou plusieurs folioles attachées au petiole commun par "une articulation, au moyen de laquelle chacune d'elles peut se "mouvoir dans certaines circonstances, et étre detachée sans "lésion, soit spontanement, soit artificiellement." *Dict. élément. de Botanique*, p. 59.

as compounded, or consisting of distinct parts, in which the divisions of the expansion, however multitudinous they may be, are still parts of the same expansion, inasmuch as they are connected by the direct and immediate prolongations of the same petiole. That the leaflets in a true compound leaf are distinct organs, is confirmed by the articulations being conspicuous by anatomy, and by the natural habits of the leaf. The articulations in many leaves are rendered conspicuous by a cartilaginous structure; and in others by a swelling of the partial petiole, at its point of union with the common footstalk, which almost impresses the idea of an artificial attachment: in some instances, however, this is so obscure, that it is by dissection only that the fact can be determined. In a longitudinal section of the petiole of a simple leaf and its ramifications, the vascular bundles distributed to the latter appear merely slips from those of the common petiole; but in a compound leaf we find a peculiar vascular arrangement, closely resembling that which occurs in the knotted culm and other articulated stems (see p. 312), marking the place where the vessels of the common petiole apparently terminate, and those of the leaflets commence; thus demonstrating the individuality of the leaflet. At this point, also, as has been already stated, the leaflets spontaneously detach themselves from the common

footstalk in autumn, in the same manner as the leaf detaches itself from the tree. Every expansion, therefore, in a compound leaf, is an individual leaf; and it assumes different forms on different plants, in the same manner as the simple leaf. All compound leaves may be arranged under the three following divisions: simply compound *(composita)*; doubly compound *(decomposita)*; more than doubly compound *(supradecomposita)*.

1. The *simply compound leaf* consists of a common petiole only, supporting two or more leaflets.

When the leaflets are sessile, attached to the apex of the petiole, and three in number, the leaf is termed trifoliate or ternate *(trifoliolatum, ternatum)*, 82; as in the genus Clover, Trifolium,

&c. It is quadrinate *(quadrinatum)*, when there are four leaflets, as in Marsilea *quadrifolia*, 83, and some of the Hedysarums: quinate *(quinatum)*, when there are five, as in Æsculus *Pavia*, 84; digitate or fingered *(digitatum)*, 85, when there are seven, as in several of the Potentillas; and *multifoliolatum* when the number exceeds seven; or *umbellatum*, 86, when being numerous they are so arranged as to form the figure of a parasol, as exemplified in many of the Lupine tribe.

When the leaflets, instead of being supported on the very apex of the petiole, are attached on its sides, the leaf is termed *yoked* and *pinnate*. It is termed simply yoked *(conjugatum)*, when one pair only of opposite leaflets is supported on a common footstalk, as in the genus *Zygophyllum*, 87, (p. 521), which is named from this character of the leaves: and *bijugum*, when there are two pairs. But the terms *bijugum*, *trijugum*, *quadrijugum*, *quinquejugum*, and *multijugum*, are not employed, except to denote the particular number of opposite leaflets on a common footstalk, when such an enumeration is requisite for establishing specific characters; otherwise all compound leaves having more than one pair of opposite leaflets attached along the side of a common petiole, are, usually, regarded as pinnate *(pinnata)*. The individual leaflets are termed *pinnæ*; and according to the

arrangement of these on the petiole, pinnate leaves receive different appellations.


When all the leaflets are in pairs, and the common petiole, or *rachis*, is not terminated either by a leaflet or a tendril, the leaf is termed abruptly pinnate *(pari-pinnatum, seu abrupti-pinnatum)*, 88; but it is pinnate with a terminal or solitary leaflet *(impari-pinnatum, pinnatum cum impari)*, when there is a single leaflet at the apex of the petiole, 89, *a.*; and the expression, with a tendril *(cirrosum)*, is added, if, instead of a leaflet, the termination be a tendril, as in the Vetch tribe, *Vicia* *, 90, *a.* If the terminal leaflet be much

* There is no specific term to designate a leaf, which has one pair of leaflets only, on a common petiole which, extending beyond them, is terminated by a solitary leaflet, as in the Kidney Bean, Phaseolus *vulgaris;* for, although the term ternate is usually applied to it, yet it cannot be regarded as ternate on ac-

larger than the other leaflets, the leaf is said to be *lyrato-pinnatum*; but this is a term of very rare application in compound leaves; those so denominated being, for the most part, truly simple lyrate leaves, altogether devoid of articulations, or that modification of vessels at the union of the lateral divisions, which is the requisite characteristic of the leaflet, and consequently of the compound leaf. If the leaflets be in opposite pairs, and it be not essential to enumerate them, the leaf is said to be oppositely pinnate *(oppositè pinnatum)*, 88; *b.b.b. b.* (page 521), and alternately pinnate *(alternatim pinnatum)*, when they are alternate, 90, *b. c.* It is interruptedly pinnate *(interruptè pinnatum)*, when the leaflets are alternately large and small on both sides of the petiole, 89, *b. c. b. c.*; jointedly pinnate *(articulatè pinnatum)*, when the common petiole is jointed betwixt each pair of leaflets, 91; and decreasingly pinnate *(pinnatum foliolis decrescentibus)*, when the leaflets gradually diminish in size from the base to the apex of the leaf, as in Vicia *sepium*. In almost every writer on elementary Botany, the term decurrently pinnate *(decursivè pinnatum)* is described as denoting that the leaflets are decurrent, or united by a foliaceous membrane, extending

count of the lateral leaflets, this term implying that all the leaflets are on the apex of the petiole; I would, therefore, propose the term *impari-conjugatum*, for the above-mentioned form of leaf. See cut, fig. 97, page 523, which is the leaf of Hedysarum *gyrans*.

from one leaflet to another, down the common petiole; but this is the description of the pinnatifid leaf; for the real decurrently pinnate is a modification of the jointedly pinnate, each joint consisting of one pair of pinnæ supported on a winged petiole (see fig. 91, page 521, *a. a. a.*). In some instances the leaflets, instead of being arranged in the same plane on each side of the common petiole, are placed around it; and the leaf is consequently termed *verticillato-pinnatum.*

2. The second division of compounded leaves, the *doubly compound*, comprehends those leaves in which the common petiole is divided into, or supports secondary petioles.

When near the apex of the common petiole, there is a single pair of secondary petioles, each of which supports a pair of opposite leaflets, as in Mimosa *unguis cati,* the leaf is termed twice paired *(bigeminatum, seu biconjugatum)*, 92: it is

thrice paired *(tergeminatum)*, when the leaf resembles the twice paired in its petiolar divisions, and has besides a third pair of leaflets at the point where the secondary petioles originate, as in Mimosa *tergemina*, 93; but if the common footstalk supports three secondary petioles on its apex, and each of these support three leaflets, then the leaf is termed doubly ternate *(biternatum, duplicato-ternatum)*, 94.

A leaf is termed doubly pinnate *(bipinnatum)*, when the secondary petioles are arranged in pairs on the common petiole, and each secondary petiole is pinnate, or displays the characters of the simply pinnate leaf, 95 ; it is conjugated and pinnate *(conjugatum-pinnatum)*, when a common petiole supports a single pair of secondary petioles, each of which is pinnate, as in Mimosa *purpurea*, 96; ternated and pinnate *(ternatum-pinnatum)*, when the common petiole supports *on* its apex three pinnate leaflets, as in Hoffmannsegia: and digitated and pinnate *(digitatum-pinnatum)*, when the number of these exceed three, as in Mimosa *pudica*.

The pedate leaf *(folium pedatum)* is generally described as a decompound leaf, composed of a common petiole divided at its summit into two diverging branches, with an intermediate leaflet, and each branch supporting two or more lateral leaflets on their anterior edge, as

in Helleborus *niger*, 98; but according to the


definition of the compound leaf which we have adopted, the pedate is merely a deeply divided simple leaf, having a close affinity to the palmate, or rather, as Sir J. E. Smith observes, who nevertheless regards it as a compound leaf, to "those "simple leaves which are three-ribbed at the base."

3. The third division of compounded leaves, the *more than doubly compound*, comprehends those in which the common petiole supports secondary petioles, which in their turn support ternary petioles.

When the common petiole supports, on its apex, three secondary petioles, which each supports three ternary petioles, and every one of these three leaflets, the leaf is termed thrice ternate *(triternatum* s. *triplicato-ternatum)*, 99, (p. 526); and when along the sides of the common petiole,

there are secondary petioles, supporting ternary, which are pinnate, it is triply pinnate *(tripinnatum* s. *triplicato-pinnatum),* as in the Carrot genus, Daucus, &c. 100, (p. 525). These are the only species of the decompound leaf; but the term is occasionally applied to leaves which are very much and irregularly divided.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There is, however, one species of the compound leaf, which we have not yet examined, because it cannot properly be classed in any of the foregoing divisions. It is sometimes termed vertebrated *(vertebratum),* and sometimes jointed *(articulatum).* It consists of several leaflets, which appear to grow out of each other, or are attached one upon the summit of another, with an evident

joint at the point of attachment, as in prickly-leaved Fagara, Fagara *tragodes* *, 100.


In the majority of plants the form of the leaf, whatever that may be, is the same over the whole of the plant; but there are exceptions to this rule; and when the diversity in the form of the leaves is constant, the term heterophyllus is occasionally adopted as the specific name of the plant. Thus various-leaved Spurge, Euphorbia *heterophylla*, is named from having the lower leaves short, wedge-shaped, emarginate and mucronate, while the upper are long linear-lanceolate, acute, and entire, 101. Heterophyllous plants, however, must not be confounded with

* Mirbel (*Elém. de Phys. vég. 2de Partie, p.* 655) quotes the leaf of spike-flowered Cussonia, a curious Cape plant, as an example of the vertebrated leaf; but this Cussonia presents an instance only of a digitated leaf, with articulated, winged, secondary pétioles.

those which have alienated leaves, as exemplified in Mimosa *verticillata* (see 102, p. 527; *a.* the form of the earlier leaves, *b.* those which succeed them); for, in these, the leaves, which are alienated or different from those which first appeared on the plant, and from those peculiar to the genus, are ultimately the only leaves of the plant.

Besides those characteristics of leaves which have been described, there are others common both to simple and to compound leaves, whatever may be their form and structure. These refer to the *situation* of the leaves; to their *disposition* on the stem and branches; to the mode of their *attachment* or *insertion;* and to the *direction* of their surfaces with respect to the stem and the branches as well as to the plane of the horizon.

In point of SITUATION the majority of leaves may be regarded as *aërial;* being suspended on the stem or the branches, in such a manner that the air is applied to both surfaces of every leaf. The position of such leaves in relation to the horizon, is determinate, or always the same in the same description of plants, but varies in different kinds of plants; and this constitutes, in Botanical language, their *direction:* in ascertaining which, the plant must be in a healthy state, for an unhealthy state of the plant and the natural decay of the leaf in autumn, alter the ordinary direction of this organ. The following are the determinate


directions of leaves which are employed in forming the specific characters of plants.

When the direction of a leaf is nearly perpendicular, it is said to be erect *(erecta)**; in which case it forms an acute angle with the stem (see the diagram, *a. a.*): but if the angle be so acute that the upper disk of the leaf is closely pressed to the surface of the stem or the branch, it is then termed *adpressa.* When the angle is moderately acute only, or about forty-five degrees (*b.*), and the surface of the leaf, consequently, approaches the line of the horizon, the direction is termed spreading *(patens* seu *patula);* and horizontal *(horizontalis* seu *patentissima),* when it spreads still more, approximating to a right angle with the stem or the branch when these are erect (*c.*), or to ninety degrees in relation to the horizon. When the leaf is spreading with a drooping apex (*d.*), the direction is termed nodding or inclined *(cernua* seu *inclinata):* it is reflex *(reflexa* seu *recurva),* when

* The term *vertical* is also employed by some writers, but it is superfluous, the position of the most vertical leaf being sufficiently described by the word erect.

the leaf forms a curve, the convexity of which (*e.*) is upwards; inflex *(incurva* seu *inflexa)*, when the convexity is downwards (*f.*); and pendulous *(dependens, pendula,* seu *demissa)*, when the whole leaf droops (*g. g.*). When the leaf is so twisted that one part of it is vertical and another horizontal, it is termed twisted *(obliquum, deviatum)*, as exemplified in oblique-leaved Garlic, Allium *obliquum;* and reversed *(resupinatum)*, when the surface which is commonly undermost is found uppermost, as in spotted-flowered Alstræmeria, Alstræmeria *pelegrina.* If all the leaves lean or point to the same side, as in Polygonatum *multiflora* (see fig. c. p. 246), the direction is termed unilateral *(secunda* seu *unilateralis)*. Some leaves, instead of being suspended in the air, lie on the surface of the ground, as for instance in several species of the genus Plantago, and the common Daisy, Bellis *perennis;* in which case the direction is termed procumbent *(procumbens* seu *humifusa)*.

In aquatic plants, the direction of the leaves is determined by their relation to the surface of the water. When the leaf is raised upon its petiole, above that surface, and is, therefore, an aërial leaf although growing in water, it is said to be emerging *(emersa)*, as exemplified in the greater Water Plantain, Alisma *Plantago:* if it lie on the surface of the water, and the up-

per disk of it only be exposed to the light and air, it is termed floating *(natans)*, as in the White Water Lily, Nymphæa *alba*, floating Water Plantain, Alisma *natans*, &c.: and when it is surrounded on every side by the water, as the majority of leaves are by the air, its direction is denoted by the term sunk or immersed *(submersa, immersa, demersa)*, as in perfoliate Pond-weed, Potamogeton *perfoliatum*. Some aquatics have leaves which are immersed and also leaves which float, as, for instance, Various-leaved Crow-foot, Ranunculus *aquatilis*, the beautiful white flowers of which decorate our ponds in the spring and summer months: others, as verticillate Water-milfoil, have both immersed and emerging leaves. In these and similar plants, it is curious to remark the manner in which the form of the leaf is modified by the medium in which it is naturally placed: the leaves, for instance, of Ranunculus *aquatilis*, which grow under the water, are divided into capillary segments *(a. a.* fig. 1, page 532), while those which float on the surface are merely lobed and notched *(b.)*. In plants even which are not aquatics, but which may happen to be planted in water, we perceive the metamorphose from the flat to the capillary leaves taking place in the fresh shoots before they gain the surface of the water, after which they assume

the form consonant to the natural habitat of the plant: *a*, fig. 2, is the natural form of the leaf of Horehound, Ballota *nigra*; when it grows on


dry land; *b. b.* fig. 3, display the change which takes place when it grows under water.

Regarding the *situation* of leaves in relation to the part of the plant on which they are seated, they may be referred to the root, the stem, and the branches, or they are *radical*, *caulinar*, and *rameal*. A radical leaf *(folium radicale)* is seated upon or springs directly from the root, as exemplified in the Primrose, Primula *vulgaris*, the Dandelion, Leontodon *taraxacum*, &c.; but radical leaves must not be confounded with *seminal* leaves, which are the first leaves of the majority

of plants proceeding from seeds that have more than one seed-lobe. The seminal leaf *(f. seminale)* is, in fact, a transformation of a seed-lobe to a leaf of a very temporary duration, and which performs the functions of a leaf until the real leaves appear, after which it drops off.

Although it may be anticipating the remarks we have afterwards to make on the nature and functions of the cotyledon, yet it is proper to state here, that the cotyledon is a nutritive organ, containing in its cells a large portion of farinaceous matter, which becomes saccharine during the germination of the seed, and is admirably adapted for the nourishment of the embryon plant. In those seeds, the cotyledons of which rise above the ground when they vegetate, as, for instance, the Lupine, the cotyledons acquire a green colour as soon as they are exposed to the light; and then, besides continuing to supply nutriment to the young plant, the root of which is still incapable of taking up any thing from the soil, perform all the functions of the real leaf. If the seminal leaves be destroyed before the other leaves appear, the plant dies; and, therefore, as the saccharine qualities of the seminal or cotyledon leaves in the Turnip attract a species of small beetle, which does not attack the proper leaves of the plant, whole crops of this useful vegetable are often destroyed. Farmers, indeed, do not consider the crop of tur-

nips safe until the second leaf appears, or, in the language of agriculture, until the plants come into *rough leaf*.

The seminal leaves, in almost every instance, are readily distinguished by their form, which always varies more or less from that of the proper leaves; thus, in fig. 4 (page 532), *a.* shows the cotyledons changed into seminal leaves, *b. b.* are the first proper leaves of the plant. A stem leaf *(f. caulinare)*, as the term implies, grows upon the stem, and is attached to it either mediately, or immediately by means of a petiole. A branch leaf *(f. rameum)* is described as such only when it differs from the leaves on the main stem of the same plant, in which case it is requisite to distinguish it from them; as exemplified in purple Cow-wheat, Melampyrum *arvense.* When stem or branch leaves are seated on joints, they are designated by the term articular *(articulares)*,

Fig. 5.


Fig. 5; and when situated close to or between the

flowers, they are termed floral *(folia floralia)*, Fig. 6.

Elementary writers usually distinguish these floral leaves, which are green and resemble the other leaves of the plant, from those which are of a different shape and colour, giving to the latter the name of bractes *(bracteæ)*, and place them among those organs which I have yet to describe under the term appendages. Both varieties, however, are real leaves, having the same anatomical structure, and differing in shape not more from one another, and from the other leaves of the plant, than these last differ among themselves. That colour is a bad cause of distinction is evident, for many plants have all their leaves coloured; and in purple-topped Clary, Salvia *Horminum*, and many other plants, the transition from common leaves to green floral leaves (*a. a. a. a.* fig. 6), and from these to coloured (*b. b. b.* fig. 6), is so gradual as clearly to display their close affinity; and to prove that all the three kinds are merely modifications of the same organ. The early Honeysuckle, Lonicera *Caprifolium;* Green Hellebore, Helleborus *viridis;* and several of the Orchis tribe, afford examples of green floral leaves: the Lavenders, *Lavandulæ;* crested Cow-wheat, Melampyrum *cristatum;* Purple bracted Monarda, Monarda *media*, &c. display specimens of those that are coloured; and several of the Sages, Salviæ,

exhibit both kinds. The floral leaves form a tuft above the flowers in the Crown Imperial, Fritillaria *Imperialis;* above those of the Pine Apple, Bromelia *Ananas,* and of several other plants; and under the flowers of Anemone, they resemble and have received the name of an involucre *(involucrum).* All these, and such-like, are therefore true leaves; but as some are more intimately connected with the flower, and in conformity with the custom of other elementary writers, I shall revert to the consideration of these as bractes, when we examine the floral appendages *.

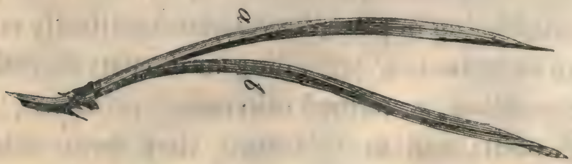
Leaves, besides differing in situation, are also variously distributed on the stem and branches.


* Linnæus remarks, that no bractes have been observed in any plant belonging to the class Tetradynamia.

The *position* is termed opposite *(opposita)*,(6.) when they appear directly on opposite sides of the stem, in pairs; and when these alternately cross each other they are said to be decussated *(decussata)*, (7.). The position is ternate *(terna)*, when the leaves stand by threes around the stem, on the same plane of the horizon; and quaternate *(quaterna)* when in fours; which, however, is not applicable when the four leaves, lying in the plane of the horizon, point towards four opposite directions, the term cruciate *(cruciata* seu *cruciformis)*, 8, being employed to denote this position. When the number of leaves surrounding the stem or branch exceed four, and point to different directions, forming a starlike figure, the position is termed whorled *(verticillata* seu *stellata)*, (9.). In the majority of instances the term whorled is used without any reference to the number of rays; but in large natural genera, as, for instance, Galium (Bed-straw), it is necessary to designate these, and for this purpose the terms *quina, sena, octona,* &c. are employed. When, instead of being in pairs, leaves stand solitarily on the stem or branches, spreading in various directions, the position is termed alternate *(alterna)*, (10, page 538); and in this state they form either a spiral line around the common axis *(spiralia)*, as in the Norway spruce fir, Pinus *Abies*; or are irregularly scattered *(sparsa)*; or they are two-

ranked *(disticha)*, (11), which implies that they spread " in two directions, and yet are not regularly opposite at their insertion," as in the


Yew, Taxus *baccata*, &c. When several leaves spring from the same point they are said to be tufted *(fasciculata)*; and the numerical terms *bina* (*a. b.*) applied when there are two leaves, *terna* when there are three, and *quina* when there are five, are used to denote the number of leaves in each fascicle.




With respect to proximity, in the distribution of leaves, the term Crowded *(conferta)* implies that their points of attachment are comparatively very

close; and imbricated *(imbricata)*, (12, and also fig. 1. Plate 4), that they partly cover each other, like the tiles upon a house-top: but if they do not overlap very closely, and the leaves regularly diverge, producing a figure somewhat resembling that of a rose, the position is termed *roselata* (13), and crowning *(coronantia)*, when they terminate the stem or its divisions like a plume of feathers, as in the Palm tribe. Remote *(remota)* is employed solely as a term of comparison, and implies that the leaves are at greater distances from one another than is usual in the majority of plants.

In whatever manner leaves are disposed on the stem or branches, the mode in which they are connected with these parts is termed their *insertion;* and the diversities of this are taken advantage of in forming specific characters. The majority of leaves are supported on footstalks; and those thus furnished, whether the footstalk be long or short, simple or compound, are said to be petiolate *(folia petiolata);* but if there be no footstalk, they are termed sessile *(sessilia)*. There are several varieties of sessile leaves: thus, if the leaves clasp the stem with their bases, they are termed embracing, or clasping *(amplexicaulia)*, (14, page 540); if the embracing leaves be opposite and united at their bases, they are said to be connate *(connata)*, (15, page 540); and *connato-perfoliata*, (16, and fig. 6.

Plate 4), if the union be in the whole, or nearly the whole breadth of the leaves, so as to give the two leaves the appearance of being united into but one leaf. Connate leaves are in some instances united by a membrane, which stretching from the margins of the opposed leaves, near the base, forms a kind of pitcher around the stem (16*) in which the rain-water is retained; as exemplified in Fuller's Teasel, Dipsacus *fullonum*, which has received its generic name διψακος, or thirsty, from this circumstance. A perfoliate leaf *(folium perfoliatum)*, (17), is itself perforated by the stem. When leaves embrace the stem with their bases, so as to enclose it as with a sheath,


they are termed sheathing *(vaginantia)*, (18, *a*.

the stem, *b. b.* the sheathing leaves); they are equitant *(equitantia)*, when being opposite they clasp each other, as in the Iris tribe; and decurrent *(decurrentia)*, when the lamellar part of the leaf runs down on each side of the stem (19. in which *a. a.* mark the leaves, and *b. b.* their decurrent portions). Some succulent leaves appear as if they were unconnected with the stem, and merely resting upon it; on which account they are termed loose *(soluta)*.


Leaves which produce spines in the same manner as the stem, are termed spiniferous *(spinifera)*, (21, page 542): when they give birth to other leaves, they are said to be foliferous *(foliifera)*, as exemplified in Duckweed, Lemna *trisulca;* and floriferous *(florifera)*, if they bear flowers, as, for instance, on the petiole in Turnera *cuneiformis*, (22, page 542), on the upper disk of the leaf in Butcher-broom, Ruscus *aculeatus*, (23, page 542): and from the serratures of its margin, in Xylophylla (24, page 542). When they

throw out roots, and produce plants in every


respect resembling the plant to which they belong, they are termed proliferous *(prolifera)*. The plant which displays the most beautiful example of the proliferous leaf is the Cotyledon *calycinum*; see fig. 1. Plate 10, in which the letters *a. a. a. a. a. a.* mark the young plants springing from the serratures of the leaf, some of them sufficiently advanced to admit of their being separated from the leaf, and sustained by their own vegetative powers. The attachment of the young plants is extremely slight, and evidently effected by a cord of umbilical vessels, originating in the proper vessels of the leaf. Leaves of this description have the closest affinity with those bulb scales which, as I demonstrated to you in treating of bulbs, produce new bulbs when they are separated

from the stem which bears them, and are planted. The young plants produced on such leaves are the lateral progeny of the adult plant, by which its existence is renewed, without the aid of the sexual stimulus; in the same manner as buds are formed on stems and branches, offsets on bulbs, and gems on tubers, to the last of which, indeed, such leaves are closely allied. They possess the same distinct vitality as tubers; for the leaves of Cotyledon *calycinum* will produce perfect plants from their serratures, if even worn in the pocket, wrapped in a piece of paper; and, holding, as they do, an intermediate place between tubers and leaves, they might be almost regarded as foliaceous tubers. It may be asked, are the germs of the plants, which rise on the margins of such leaves, coexistent with the origin of the leaves, as is the case with the germs in the eye or gem of the tuber? To answer this question we must have recourse to the microscope; and on examining with it the margins of those leaves of Cotyledon *calycinum*, which have not yet become proliferous, we perceive in each serrature a small rough papilla, projecting on the under disk of the leaf; and in a transverse section the cellular matter at this place is seen to be differently arranged from that in the rest of the leaf; and displaying in its centre a small opaque point, from which a vessel extends to the surface of the

papilla, while another enters the surrounding cellular matter. This point is the germ of the new plant; and the vessel, or rather fascicle of vessels, entering the cellular matter is its umbilical cord. As soon, therefore, as circumstances favourable to its evolution are present, the same vital actions commence in it to promote its growth, and for the formation of new parts, as occur in gems situated on tubers; the leaf, like the tuber, supplying the necessary nutriment, until the roots of the young plants are capable of taking up the nutritious fluids of the soil; after which it decays, its assistance being no longer required. In tracing the progress of the germ, we perceive that the radicles shoot out from the surface of the rough papilla; while the two first leaves of the young plant, imperfectly developed and applied face to face, push out from the edge of the serrature on the same plane as that of the surface of the leaf; but the young plant afterwards turns upwards, so as to rise and stand erect on that surface. These two primordial leaves are always developed, and sometimes expanded, before the radicles make their appearance. But the real proliferous leaf, such as that of Cotyledon *calycinum*, must not be confounded with leaves which became proliferous only when separated from the tree and planted in the ground, under favourable circumstances; as, for example, those of the Lemon tree;

which are never productive while they remain attached to the parent. These leaves, however, closely resemble the scales of the scaly bulbs; each scale of which produces a young bulb when it is separated from the others on the same caudex, and planted, although one new bulb only is the result of the united functions of all the scales, when they are allowed to remain as aggregated parts of the adult bulb: and the explanation which has been already given (see pages 176-177) of this circumstance, as it occurs in bulbs, is applicable to its occurrence in this description of leaves *.

* It is rather extraordinary, that although the inhabitants of the Radick islands, lately discovered in the Pacific Ocean (see *Kotzebue's Voyage)*, are aware of this fact, and constantly raise their Taro, Arum *esculentum*, by planting the leaves; yet, it was unknown in Europe until the middle of the seventeenth century; when Agostino Mandirola, an Italian minorite of the Franciscan order, first described the art in a small work entitled, *Manuale de Giardinieri*, published at Venice, in the year 1684. The leaves he planted were those of the Cedar and the Lemon, and the mode of conducting the operation, which he thus describes, is, I believe, still followed: "Hò "preso un vaso pieno di buonnissima terra sottile e grassa, poi "intorno all orificio vi hò posto le foglie con il gambo sotto terra "tanto che resti meza la folia sopra; poscia hò fatto un' orcio-"letto d' acqua che a stilla inaffiasse esse foglie, almo do detto di "sopra, aggiongendovi sempre terra nel scavo dell acqua, ed in "tal modo hanno fatto presa, e gettato fuora le vergelette "in breve tempo." For other particulars on this subject see *Beckman's Hist. of Inventions*, vol. iii. p. 426. Trans.

The size of leaves differs very considerably in different species of plants; but, as has been correctly remarked, "it is not always the largest "plant that has the largest leaf*." The Burdock, Arctium *lappa*, produces larger leaves than any other British plant; but these seldom exceed three feet in length, and two and a half in breadth; whereas the leaves of the Banana, Musa *sapientium*, are sometimes found ten feet in length by two in breadth; and those of the Talipot Palm, Licuala *spinosa*, have been known to exceed thirty feet in circumference †.

Having now concluded our examination of the external or physiognomical characters of leaves, we have next to investigate their internal structure or anatomy. To pursue this inquiry, however, with advantage, some mode of classifying leaves, in reference to their structure, should be adopted. As all leaves have more or less affinity, in point of structure, to the stems on which they are produced, we might adopt the same arrangement that we followed in our inquiries into the nature of stems, and examine them as they belong to *acotyledonous*, *monocotyledonous*, and *dicotyledonous* plants; but the varieties of structure which each of these

* *Keith's Syst. of physiological Bot.* i. p. 37.

† These leaves, which are fan-shaped, when propped up on one side with a pole, serve as a temporary hut or shade to the natives of Ceylon, who sell their merchandise under them.

classes present, and the difficulty of pointing out the general features which should be regarded as the fixed characteristics of each class, present too many difficulties to permit the adoption of this arrangement. Equal difficulties occur to render objectionable any classification founded on the form, or the substance, or the arrangement of the parts of leaves. The only plan, therefore, that we can adopt to render our investigation methodical, is to discover in what circumstances all leaves agree; and to examine the nature of these, with their modifications in the three great divisions of plants which we have just noticed.

In the most cursory examination of the majority of leaves, we perceive that these organs are composed of three distinct parts: one part, firm and apparently ligneous, constitutes the framework or skeleton of the leaf; another, succulent and pulpy, fills up the intermediate spaces of this framework; and a third, thin and expanded, incloses the other two, or forms the covering for both surfaces of the leaf. On a closer examination we find that the first of these parts is *vascular*, the second *cellular*, and the third a transparent *cuticular pellicle.* Admitting, therefore, that these parts are present in every leaf, although we may not be able to discover all of them distinctly, owing to the imperfection of our instruments; we may conduct our inquiries into the structure of

leaves in reference to their *vascular*, their *cellular*, and their *cuticular* systems.

*a. Of the vascular system of leaves.*

Among fallen leaves which have been exposed to the action of the atmosphere in a damp place, or which have dropped into a pond, we generally find some in which the cuticle and pulp are completely destroyed; whereas the ribs or veins, as they are commonly but erroneously termed, being less susceptible of decomposition, remain almost entire, and display the appearance of a beautiful tissue of network, more or less complicated. This is the vascular system of the organ, and the leaf in this state is termed a *skeleton leaf*. Leaves are frequently artificially made into skeletons by macerating them in water until they begin to putrefy, when the cuticle is easily separated by gently rubbing and pressing them; and the pulp washed out from between the meshes of the vascular network by rinsing in water: and if the operation be carefully performed, the most minute cords of vessels may be preserved* (see fig. 2, Plate 10).

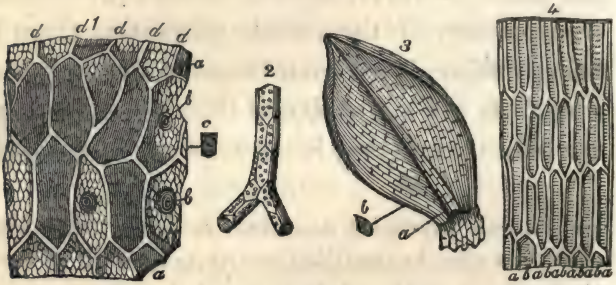
* Although skeleton leaves produced by spontaneous decomposition must have been very early observed, yet they were not artificially prepared until 1645, when Marcus Aurelius Severinus published a figure, with a description of a leaf of Cactus *Opuntia* reduced to a skeleton. The art, however, was little attended to, until it was revived by Ruysch, in the commencement of the eighteenth century. This naturalist at first prepared them, by covering the leaves with insects, which ate away the pulpy part; but as these anatomists, or satellites, to

These preparations enable us to trace more readily than in the natural leaf, the divisions, subdivisions, and various ramifications of the vascular fasciculi; but beyond this they afford us no information, and we must have recourse to the microscope to obtain a satisfactory knowledge of the vascular structure of leaves.

If we commence our investigation with the simplest description of plants, the Lichens and the Mushroom tribe *(Fungi)* for instance, we perceive, even by the assistance of the best glasses, scarcely any trace of a vascular structure, the whole plants appearing to be little more than an aggregation of cellular substance enclosed in a cuticle. This appearance, however, arises in some degree from the transparency of the vessels preventing them from being distinguished from the cells, and in some degree from the simplicity of their structure; for, as the fluid they convey is not required to be raised to

use his own expression, sometimes made sad havoc with the solid parts also, he soon dismissed them from his service, and employed the method I have described in the text (see his *Adversariorum Decas tertia*, Amst. 1723-40). Fruits were also prepared by the same method; and the description of the interior structure of a pear, by Du Hamel, illustrated with engravings, may be seen in the *Mémoires de l'Académie des Sciences*, An. 1730-32. In the Philosophical Trans. 1730, No. ccccxiv. p. 371, Francis Nicholls gives an account of the skeleton of a Pear leaf, the network of which he split into two equal layers.

considerable heights, as in the more perfect plants, the conducting tube is consequently more simple. If, however, we take a plant in which the vessels convey a colourless fluid through a coloured cellular structure, as, for example, Marchantia *polymorpha,* we find that the surface of the lobes of the leaf-like frond, when examined by an ordinary lens, is reticulated by depressed lines, within each of which a small nipple-like body rises. When a thin slice (1. *c.*) of a lobe is placed under the microscope, these lines are discovered to be occasioned by vessels which run immediately under the cuticle, anastomosing with one another, as represented at 1. *d. d. d. d.*; and the papillary




bodies are seen to be cuticular pores surrounded by a slight elevation of the cuticle (1. *b. b.*) modified as shall be afterwards described. This vascular network is formed by a single porous tube, branching and anastomosing so as to form irregular, lozenge-shaped meshes, which are filled with a dark-green cellular parenchyma.

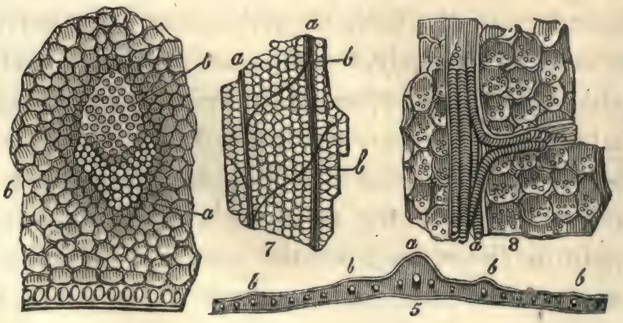
The vessel itself is closely connected with the cellular matter, and when separated (see 2, a highly magnified representation), bears the marks of the cells on its sides. We find nearly the same vascular structure in the Mosses. Thus, if we take a leaf of broad-leaved Bog-Moss, Sphagnum *obtusifolium*, as a specimen, we find it, when magnified as at 3 (*b.* shows the natural size of the leaf), consisting of a midrib (*a.*), on each side of which are many oblong cells, arranged apparently in straight lines: but, under the microscope, these oblong cells are seen to consist of elevated cuticle (as at 4. *b. b. b. b. b.*) in the meshes of a reticulated vascular system (4. *a. a. a. a.*), too minute to allow of the nature of the vessel to be made out by the aid of the highest magnifying powers. It is probably the same as that of the vessels of Marchantia. The leaves of all the Mosses are sessile, although many of them are sheathing; and most of them are furnished with a midrib; but their minuteness prevents any certain information being obtained as to the manner in which the leaves receive their vessels from the stem, or whether there be a distinct set of returning vessels: they appear to be merely a continuation of the vessels of the cortex of the stem. Sprengel asserts that in the Sphagnum before us, both the cells of the leaf and those on the surface of the

stem contain a fine spiral fibre; which, however, I have not been able to discover.

Proceeding to the next division of plants, those produced from *monocotyledonous seeds*, we observe the costæ or vascular fasciculi distinguishable by the naked eye; of different sizes, and running in gently curved or nearly straight lines, either from the base to the apex, or transversely from the midrib to the margin of the leaf. The former is found chiefly in those leaves which have no decided petiole, but spring directly from a bulb or a tuber; the latter in those which are petiolated. We shall examine each kind separately.

A bulb leaf of the White Lily, Lilium *candidum*, may be taken as an example of the general distribution and character of the vascular system in the first description, the *sessile leaves* of monocotyledonous plants. On examining it, we find that the vascular framework consists of a distinct midrib, which forms the keel of the leaf, and of less elevated ribs *(costæ)*, that extend on each side of the midrib in longitudinal lines, which form a gentle curve, following the shape of the leaf. In the smoother and more succulent leaves of this division, however, these costæ are scarcely visible externally, or at least appear merely as striæ on the surface of the leaf: and this is the case, also, as far as regards many of the smaller vascular fasciculi, even in those leaves, which have

prominent costæ. If we now make transverse and longitudinal sections of the Lily leaf, we perceive that the costæ are composed of fasciculi of spiral vessels closely accompanied with corresponding fasciculi of proper vessels, and embedded in cellular substance; or, that the leaf has a double system of vessels, one for conducting forwards the sap, and the other for returning the proper juice into which the sap has been changed by the functions of this organ. In the transverse section, these vascular bundles appear like dots upon the divided surface; and, when magnified in transmitted light, display their twofold nature by difference of transparency; the part of each fasciculus composed of spiral vessels being particularly distinguished by a greater degree of opacity, owing to the spiral thread which composes the coats of these vessels being firmer and more opaque than the coats of the proper vessels. Thus, in the midrib (5. *a.*), we perceive that the three spots



formed by the vascular fasciculi, which it encloses, have each one half darker than the other, and the darker half is turned towards the upper disk of the leaf. The same circumstance characterizes the fasciculi enclosed in the costæ (5. *b. b. b. b.*); and also those of the intermediate or secondary ribs, which form no prominence on either surface of the leaf. By the aid of more powerful glasses, the distinct character and disposition of both kinds of vessels are perfectly perceptible: and in placing the principal fasciculus of the midrib, detached from the others, under the microscope, this is not only satisfactorily demonstrated, but we become acquainted, also, with the fact, that the spiral vessels (6. *a.* page 553) of the leaf as well as those of the stem, are found generally empty, like the arteries of animals; while the proper or returning vessels (6. *b.*) are always full. I may here remark, that the closer proximity of the spiral vessels to the upper disk of the leaf is common to the majority of leaves; for, independent of the fact, that the chief function of these organs, namely, the exposure of the sap to the light and air, would lead us, *à priori*, to conclude that the vessels carrying forwards the sap must, necessarily, be on that side of the leaf most exposed to these agents; the sap-vessels receiving their origin in the stem from the vessels of the alburnum, and the returning vessels terminating in

those of the bark, the disposition could not well be otherwise, seeing that the relative position of the upper and under disk of every leaf, to the centre of the stem, is exactly that of the alburnum and the bark. In leaves, however, which stand vertically, or have no distinction of surfaces, the situation of the spiral vessels is either the reverse, or in the centre of the entire vessels: anatomy thus confirming the idea of the close affinity of such leaves to stems.

I have already stated that the bundles and threads of vessels, in leaves belonging to this division of the class of leaves under consideration, run in longitudinal lines. These are not exactly parallel, but approach both at the base and the apex of the leaf; and, also, communicate laterally in their course by small threads, given off at irregular intervals. This structure is easily demonstrated by placing a small slice of the Lily leaf (7, page 553), cut immediately within the cuticle of the upper disk, under the microscope. We perceive that the longitudinal bundles (*a. a.*) are united by transverse threads (*b. b.*); and this is the case at irregular intervals throughout the whole extent of the leaf.

These transverse fasciculi, however, are not threads simply detached from one longitudinal layer, and coming into contact with another, as was supposed by Dr. Grew to be the case in all

leaves*; but are distinct vessels, uniting with the longitudinal bundles in a singular manner, as is apparent (8. *a.* page 553) in a very highly magnified view of one of the angles formed by a transverse fasciculus and a longitudinal vascular cord. One of the vessels appears to belong to the longitudinal fascicle; but the other terminates there, and has its extremity applied to the side of one of the vessels forming a part of the longitudinal fascicle. Whether there is any opening directly into the longitudinal vessel on which the extremity of the transverse vessel is applied I have not been able to determine. From these demonstrations we may conclude that the vascular system of the sessile leaves of monocotyledons, consists of fasciculi composed of spiral vessels accompanied with proper vessels which are not spiral, arranged in longitudinal lines, and connected by smaller transverse threads; the whole forming a reticulated texture with irregular rhomboidal meshes. The longitudinal vessels are a continuation of those which are nearest to the surface, in the root caudex, or the stem from which the leaves immediately spring; and thus

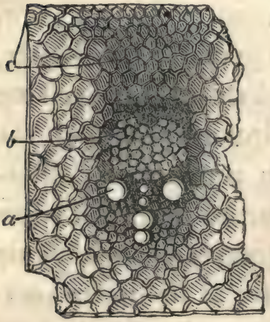
* It is bold to dissent from such authority on the subject of vegetable anatomy; but the improvement of microscopes since Dr. Grew's time, has enabled many Phytologists of very inferior abilities to that great man, to point out some errors into which he had been led by the imperfection of his instruments.

the greater number of the circles of the distinct fasciculi, which compose the stems of monocotyledons, terminate in leaves until the plant attains its ultimate growth.

In order to examine properly the vascular framework or skeleton of the *petiolated* leaves of monocotyledonous plants, we must arrange them under two subdivisions. 1. Those in which the *ribs run longitudinally*, or in a direction from the base to the apex of the leaf: and, 2. those in which they run *nearly transversely*, or in a direction from the midrib to the margin.

1. In this subdivision we perceive that, in the Grasses, the vascular fasciculi resemble, very closely, those of the former division: the ribs being in longitudinal, nearly parallel lines, converging towards the apex of the leaf; and united at irregular distances by obliquely transverse threads. If we take a stem leaf of Indian Corn, Zea *Mays*, as a specimen, we perceive the petiole, which is broad, expanded, and sheathing, deriving its origin from the whole circumference of the knot of the articulation which produces it; dilating gradually as it rises upwards, until its edges become a thin fimbriated membrane, and again contracting, but less gradually, at its upper part, or where it is united to the expansion of the leaf. The vascular bundles, which can be readily traced by the naked eye, are composed of the two distinct

kinds of vessels described in the former division, which appear as dots in a transverse section of the petiole situated almost close to its external surface; or as represented at *a.a.a.a.* (9.), a highly magnified view of the section. The number of the spiral vessels in each fascicle is generally six, three large and three smaller, symmetrically arranged, as may be seen in a transverse section of one of the fasciculi (10. *a.*) viewed under the microscope; and the whole surrounded by a mass of much denser cellular matter than the rest of the substance of the petiole. The returning or proper vessels (10. *b.*) are much smaller and more numerous than the spiral; and are congregated into a bundle which occupies a space close to the former, between it and the cuticle, and is bounded by a mass of the same dense cellular matter (10. *c.*) as that which

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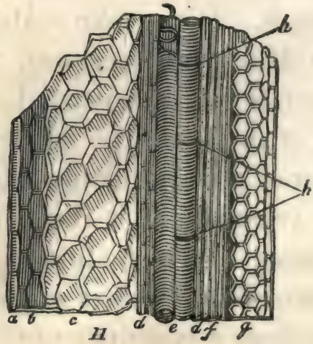


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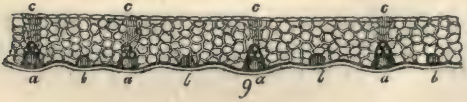


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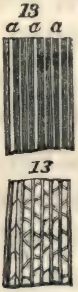
surrounds the spiral vessels: the object of which is, probably, to give such a degree of firmness to the petiole, as will enable it to sustain, in the erect position, the expansion of the leaf. If we now make a vertical section of the petiole, so as to divide one of the fasciculi longitudinally, in the thickness of the petiole we perceive that the larger vessels are regular spirals (11. *e.*), furnished with diaphragms (*h.*) at certain distances, the structure of which, however, we shall perhaps never be able to ascertain, owing to the minuteness of the parts; the diameter of these vessels, although comparatively large, not exceeding $\frac{1}{300}$ of an inch. In this section, also, we perceive that the proper vessels (11. *f.*) are membranous and porous: and that the cells in immediate contact with both sets of vessels are oblong (11. *d.*); whereas those (*g.*) which are between the proper vessels and the cuticle of the outer surface of the leaf, and which form the elevated portion of the costa, although they are not oblong, yet, differ both in size and in regularity of structure from those (11. *c.*) that form the inner substance of the petiole. Close to the cuticle of the upper disk (11. *a.*) is a mass of oblong cells (*b.*) resembling those in contact with the vessels.

Ascending to the expansion of the leaf, which is separated from the petiole by a semitransparent white, condensed, membranous space (see cut

12. *c.*), from which the expansion of the leaf spreads out like a shoulder on each side; we perceive that the midrib (12. *b.*), which is not distinguishable in the lower part of the petiole (12. *a.*), becomes very conspicuous on the under disk at this point; forming almost a knob, which passes into a striated ridge, and extends, gradually diminishing in size, to the apex of the leaf. From ten to twelve parallel costæ are visible on each side of the midrib, which when magnified appear like white parallel lines (13. *a. a. a.*), running through the green smooth substance of the expansion, and taking the curve of its shoulders as if originating in the white semitransparent space (12. *c. c.*) already described. But between these costæ there are several smaller vascular cords, which are scarcely visible on the surface, neither producing elevation nor difference of colour; and which can be demonstrated only on the dissection of the leaf. One of the more obvious distinctions, therefore, in the structure of the petiole and the expansion


in the leaves of the gramineous tribe of plants is, that, in the petiole, the vessels run in distinct fasciculi, which are all nearly equal in point of size (14.); whereas in the expansion the fasciculi differ considerably in size (13.), the larger only being very visible on the surface. In both, there are transverse threads which connect the longitudinal bundles, and these are conspicuous even to the naked eye in the more succulent leaves, particularly in those which involve the fructification of the Mays (15.), when viewed by transmitted light.

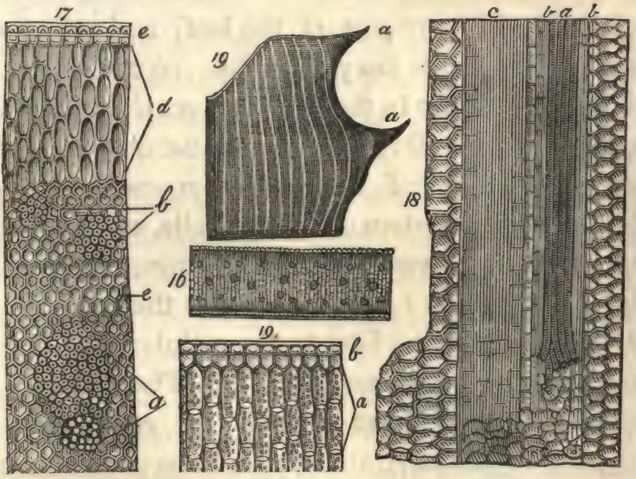
In examining a transverse section of a portion of the expansion, of the leaf of Indian Corn, containing one of the visible costæ and the interval between it and the next costa; we immediately perceive the difference of structure in the two kinds of fasciculi. The visible costa consists of two large spiral vessels on the same line, and a compact fasciculus of proper vessels on each side of the line of spirals, towards both surfaces of the leaf (*c. c.* fig. 13, Plate 10); while, in the interval, each fasciculus is composed of one small spiral vessel only, surrounded with a circle of proper vessels, and placed in the heart of the substance of the leaf (*d. d. d.* fig. 13, Plate 10). But, besides these, there is another kind of fasciculi, two of which are generally observed in each space between the visible costæ, connected with a pe-

culiar cellular apparatus to be afterwards described. These appear to be modifications of the two vascular fasciculi already noticed; having the same structure as the obscure or invisible fasciculus, and the accompanying compact bundle of proper vessels of the visible costa (see *e. e.* fig. 13, Plate 10). In a section obtained by slicing the leaf, we find all these fasciculi united by transverse threads, forming rhomboidal meshes, similar to those which have been already described.

But although the arrangement of the vascular system of the leaf of Indian Corn, just described, may be taken as a specimen of that peculiar to the leaves of all the Grasses; and to those leaves of monocotyledonous plants which are petiolated, and furnished with longitudinal costæ, yet, there must necessarily be many modifications of this arrangement. I shall, however, particularly notice one only, that which characterizes very thick and fleshy leaves; such, for instance, as those of the Aloe tribe.

On the exterior surface of the leaf of the Aloe, and other leaves of a similar character, we perceive no appearance of a vascular system; but on attempting to tear the leaf across, considerable resistance is opposed to the effort, by a number of tough, longitudinal fibres. These constitute the vascular fasciculi; and in a transverse section of the leaf, we find that they run through its sub-

stance, nearly in the same manner as the fasciculi in solid monocotyledonous stems. Viewing the section (16.) through a magnifying lens, we perceive that the fascicles are of different sizes, the largest being in the centre: and, in a portion of it (17.) placed under the microscope, we perceive that the central fasciculi (*a.*) differ from the others (*b.*), in their structure as well as size, being composed of a dense cord of spiral vessels, accompanied by a very large bundle of proper vessels, which is separated from it by a thin layer of cellular substance;

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whereas the smaller or marginal fascicles appear to be entirely composed of proper vessels. This structure of the central bundles is still more decidedly observed, in a very thin longitudinal slice,

(18.) cut in the thickness of the leaf, and viewed in the microscope by transmitted light. The cord of spiral vessels (*a.*) is a few proper vessels surrounded by, and a layer of cellular matter interposed between it and the large fascicle (*c.*) of proper vessels. In splitting the leaf, we perceive that these vascular fasciculi run in parallel lines (19.), and take the same curves as the margin; but do not enter into the spines (*a. a.*), which are of a hard ligneous consistence, and supplied by small threads of vessels given off from the fasciculi nearest to them. The vascular cords do not anastomose in any part of the leaf; and very few transverse threads are perceptible, compared with those which occur in the membranous leaves of this natural order. But besides the vascular fasciculi we find, in this leaf, and other monocotyledonous fleshy leaves, a system of tubular cells, which might be mistaken for vessels, situated immediately under the cuticle (17. *d.*), from which they extend in straight contiguous lines to the cellular parenchyma, the chief substance of the leaf. These resemble beaded or moniliform vessels (*les vaisseaux en chapelet* of Mirbel), and appear to be composed of transparent membranous oblong vesicles, united at their extremities; and are either perforated, or contain small granules sparsely spread over their inner surface (19. *a.*). It is probable that these cells are part of the absorbing system by which fleshy plants, such as the Aloe, which grow

in sandy, arid soils, chiefly derive their nourishment: for, as very little moisture is taken up by the roots, these plants are supported, almost entirely, by cuticular absorption. The natural functions of these tubular cells, also, being to absorb and to carry fluids towards the centre of the leaf, enable us to understand why the leaves of an Aloe, when separated from the stem, are very long in drying and losing their plumpness; whereas, if thrown into water, when they are very much shrivelled, they almost immediately regain their original size. The absorbing mouths by which they are supplied will be demonstrated, when we examine the cuticular system of leaves.

In the leaves of those monocotyledonous plants the costæ of which, instead of being longitudinal, run in transverse parallel lines, forming acute angles with the midrib, we find that the arrangement of the vascular framework resembles that of the Grasses in some circumstances; but differs from it in other respects. Thus the costæ are parallel to one another, and communicate by small transverse cords of vessels, so as to form meshes which are rhomboidal or square according to the angles at which these transverse cords are given off from the costæ, as in the Grasses. The petioles are, also, in general sheathing, and many of them are furnished with ligulæ. But, in almost all of them, the peculiar cartilaginous articulation, which divides the petiole

from the expansion in the Grasses, is not present; and the petiole assumes a stalk-like aspect before it reaches the expansion.

Taking this leaf of Canna *Indica* (21.), as a

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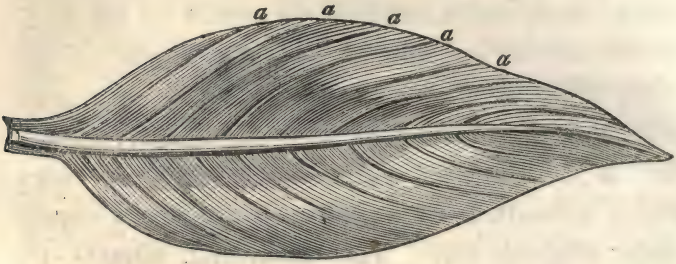
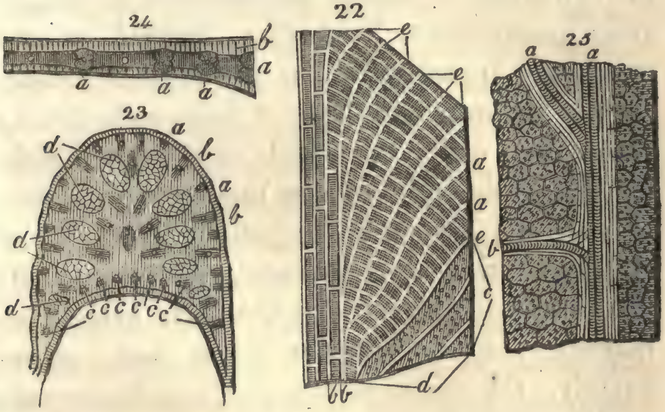



specimen of the vascular system in this description of leaves, we perceive, looking at the under disk, that the midrib is much elevated near the base, and gradually diminishes in size, until it appears little more than a mere line at the apex of the leaf. The more elevated costæ (*a. a. a. a. a.*) are the primary vascular fasciculi; and between these are secondary fasciculi, which are less elevated. To the unassisted eye they all appear to go off from the midrib; but viewed by a magnifying lens, and with transmitted light, we perceive that all of them do not proceed directly from the fasciculi of the midrib (22. *b. b.* see page 567), but that some of them (22. *a. a.*) are branches of the others*. At

* In figure 22, the cuticle, except at the space *c. d.* is taken off, and the midrib pared down, to show the transverse vascular threads, which unite the parallel fascicles; and which are rendered very conspicuous when viewed by transmitted light,

the margin they all inosculate, and form, as it were, one fasciculus which, extending from the base to the apex, is the real living boundary of the leaf.

Pursuing our examination more closely; and placing a slice (23.) of the petiole cut transversely near the base of the expansion, under the microscope with a glass of a moderate power, we perceive that the vessels are arranged in distinct fasciculi, which are nearly of the same size in the centre of the section; alternately larger and smaller (23. *a. b. a. b.*) near the circumference on the convex surface, or that part of the petiole which is towards the under disk of the leaf; and all small




(*c. c. c. c. c. c.*) on the concave surface. The costæ (22. *e. e. e.*) are continuations of those on the con-

owing to the dark green colour of the parenchyma in the meshes formed by these threads.

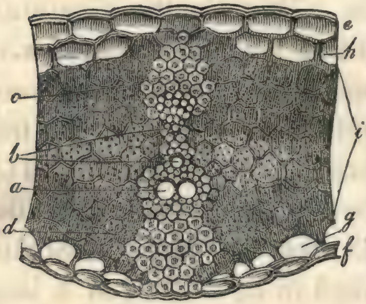
cave surface of the midrib, which are curved outwards in opposite pairs, at different distances between the basis and the apex of the leaf; but the central fasciculi pass on its apex. These vascular fasciculi are embedded in a cellular tissue; besides which the petiole and midrib of this description of leaves contain peculiar pneumatic or air cells (23. *d. d. d.*) closely resembling those which I shall afterwards demonstrate to you, constitute a great part of the substance of aquatic plants. In a transverse section of a small part of the expansion of the leaf (24. see page 567), we perceive that the vascular cords (*a. a. a*) run nearly in the centre between the two plates of cuticle, embedded in an opaque green parenchyma; and that, instead of the pneumatic apparatus of the petiole and midrib, there is a transparent layer of large cells (24. *b.*) immediately under the cuticle of the upper disk. I should, however, inform you that these pneumatic cells are not present in the petiole and midrib of all leaves with transverse costæ, belonging to monocotyledonous plants; but the same general arrangement of the vascular cords, and, consequently, the same structure of the framework, are seen in all of them.

With regard to the composition of the fasciculi; these, as in the other leaves we have examined, consist of spiral and proper vessels; differing, however, in the relative position of the spiral vessels, which in each fasciculus, in these

leaves, are placed between two bundles of proper vessels. If we cut a superficial slice from the under disk of the leaf, where any of the fasciculi ramify (25. see page 567); and examine it by a powerful microscope, we may rationally conclude from what we perceive, that, although some of the costæ are merely continuations of the vascular fasciculi of the midrib, separated like threads from a skein of silk, yet that others which also branch from these, and the smaller transverse vascular threads, are actually united by that kind of connexion which, in the vessels of animals, is termed anastomosis. Thus, in the slice under examination, we find that both the fasciculi (*a. a.*) contain the same number of vessels, which would not be the case, were the one parcel separated from the other; and although the transverse thread (*b.*) contains one spiral vessel only, yet this vessel does not appear to be split from the larger fasciculus; but to be simply united to it, the end of *b.* being evidently applied to the side of *a.* if it do not actually open into the cavity of that vessel.

Examining, by the same power of the microscope, a transverse section of one of the larger fasciculi of the midrib of the leaf of Canna *Indica*, we find it to consist of one large, and from three to six smaller spiral vessels, arranged and relatively connected with the proper vessels in a manner closely resembling the arrangement of those in the fasciculi which are found in the

stems of White Bryony (see fig. 4, A. Plate 8). The arrangement of the vessels, however, in the fasciculi of the expansion differ, in some degree, from those of the midrib. Placing a transverse section (26.) of one of these fasciculi under the microscope, we find that it is composed of two large tangent spiral vessels (*a.*) surrounded by firm cellular matter; and of two small isolated vessels (*b.*), which are spirals also, situated nearer to the upper disk of the leaf; the one before the other, and, in like manner, surrounded by firm cel-

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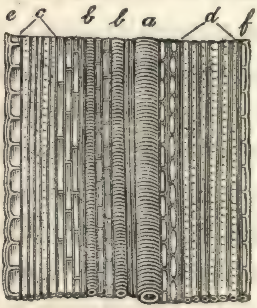


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lular substance. The proper vessels are collected into two distinct fasciculi; the largest of which (*d.*) is on the under disk or back of the leaf, and covered by the cuticle only, while the smallest (*c.*), which is towards the upper disk, is covered by one layer of cellular substance. In the longitudinal section (27.) made through the centre of the fasciculus, in the thickness of

the leaf, *e.* being the upper and *f.* the under disk, the relative situation of the vessels is still more clearly demonstrated.

We may pause here a few moments to remark, that the colour of the juice in the cells of the leaf, is more intense towards the surfaces, while in the centre it is scarcely deeper than that which is contained in the cells of the cutis (*e. f.*). Is not this probably owing to the sap which is current in the spiral vessels, and which is colourless, being given out laterally, and diffusing itself through the cells, in which the change effected by the air and light, that causes the colour is produced? The manner in which the colour is diluted as it approaches the limits of the spiral vessels, would authorize such a supposition; but, wherefore it may be demanded, are the cells immediately under the cutis free from colour? It is probable, we may reply, that these cells are filled by pure water only, absorbed from the atmosphere; and, consequently, their contents are unfitted to undergo those chymical changes to which the sap is subjected in the leaf. But this discussion is premature.

From this demonstration of the vascular system in the leaves of monocotyledonous plants, it is evident that a general character, however variously modified in many instances, pervades the whole. The fasciculi of vessels are distinct; they run in directions parallel to one another;

and the principal bundles are united by smaller transverse cords or fasciculi; which form meshes of a rhomboidal figure, all nearly of the same size in the same leaf.

Passing on to the leaves of *Dicotyledons,* we find the reticulated structure of the vascular framework more complex and varied, than we have found it in the leaves of the two natural divisions, which we have already examined. This is made evident to the unassisted eye by holding up between it and the light any newly expanded leaf; but it is more beautifully demonstrated in the skeleton of a full-grown leaf, carefully prepared. In a leaf of the Indian Fig, Ficus *religiosus,* thus prepared (fig. 2, Plate 10), we perceive seven principal costæ, springing from each side of the midrib (*a.*), and extending to the margin of the leaf, where they bend towards its apex, and are enarched or inosculate with one another (*b. b. b. b.*). From each side of these costæ, a series of secondary fasciculi spring, which, inosculating, also, with their opponents, form a secondary set of arches (*c. c. c. c.*) between each pair of the principal costæ; and inclose a tissue of minute and exquisitely beautiful reticulations, the result of the numerous ramifications of the vascular threads, as they divide and subdivide as it were out of a greater into a less. But besides this distribution of these vascular fasciculi, we observe a fascicle (*d. d.*), proceeding from each

side of the midrib, at the very base of the expansion, and bounding the margin of the leaf. This receives supplies from the arches of the costæ, as it passes onwards, until it unites with its fellow at the apex of the leaf. Such is the general distribution of the vascular fasciculi in the leaves of *dicotyledonous* plants. It would be inconsistent with any elementary plan of instruction, to enter largely upon the consideration of the various circumstances which modify the distribution of these fasciculi; and, therefore, I shall examine the modifications depending upon two states only of dicotyledonous leaves: 1. When the leaf or its expansion is *thin* or *membranaceous;* and, 2. when it is *thick* or *fleshy*.

1. The general distribution of the vascular fasciculi, in *thin leaves* of dicotyledonous plants, in the majority of instances, resembles that which we find in the skeleton of the leaf of the Indian Fig tree. The vessels of the costæ proceed from the principal fasciculus of the midrib, and run between the laminæ of cuticle, embedded in the cellular matter, in cords which form visible elevations on the back of the leaf, and corresponding furrows on its face. Each fascicle consists of spiral and proper vessels throughout all its ramifications; and, in whatever manner these vessels are arranged in the fasciculi, the spiral and proper vessels are always associated and, in general, tangent. This arrangement is common both to sessile and to petiolated, to

simple and to compound leaves, as far, at least, as respects the expansion. In sessile leaves, however, all the fasciculi do not proceed from the midrib, but some are given off directly from the stem or the branch, and enter the expansion of the leaf at its base, on each side of the midrib. In petiolated leaves, also, the petiole is generally dilated at its point of union with the branch, and at this point the vessels enter the petiole in distinct bundles; the remains of which are visible in the eschar produced by the falling of the leaves in autumn.

Thus in the Apple, the Pear, the Peach, and many other trees, the leaf is attached to the wood by three fasciculi, one of which enters the middle of the petiole, and the others on each side of it. In the Lilac, the attachment is also by three distinct fasciculi; but there is besides a line of coalesced fasciculi which forms a kind of open crescent; and in the Laurustine the whole of the vessels pass from the wood into the petiole in one fascicle, the transverse section of which is nearly a complete semicircle. In compound leaves, the number of fasciculi passing into the petiole from the wood, is in some instances regulated by the number of the leaflets; in the Elder, we find generally five; and in the Horse Chesnut, from five to seven or eight. It is, however, the inner part only of these fasciculi, or that which con-

veys the sap to the leaf, that is given off from the wood, or rather from the medullary sheath; for the outer part, which consists of the proper or returning vessels, enters the bark, but not the wood. This fact is beautifully illustrated by placing young leafy twigs in coloured fluids. The colour is seen passing up from the stem into the leaf through the upper portion of each fascicle; while that part which consists of the returning vessels remains perfectly free from colour.

Such is the general arrangement of the vascular framework in the thin leaves of dicotyledonous plants; to examine the intimate structure of the fasciculi, we must have recourse to the same method that we adopted in our examination of them in the leaves of the two natural divisions we have already investigated. Taking the leaf of the Lilac, Syringa *vulgaris*, as an example of the simple *petiolated* leaf; and placing a thin transverse slice of the petiole under the microscope, we find that the vessels are arranged in the following manner. Close to the upper or channelled surface of the petiole, we find three small distinct fasciculi of spiral vessels (*c. c. c.* fig. 10, Plate 8), one immediately within the cutis, in the hollow of the channel, and one at each side; but the principal vessels constitute one large compound fasciculus, in the centre of the petiole, which appears of a horseshoe shape, in the transverse section; and

consists of one fasciculus of spiral vessels, and two fasciculi of proper vessels. The spiral vessels, which form the central fasciculus (*d.*), are arranged in rays, which are sometimes tangent, at other times separate; whereas the proper vessels constituting the two fasciculi (*e. e.*), one of which is situated within, and the other without the fasciculus of spirals, are irregularly embedded in a pulpy parenchyma, and are readily distinguished by their greater transparency. The bark, or true cutis (*a.*) of the petiole, seems, also, to consist chiefly of several series of the same kind of proper or returning vessels. In the various modifications of this structure of the vascular system, in the petioles of dicotyledonous leaves, the radiated arrangement of the spiral vessels is found in all: the petiole in this respect, as well as in the other parts of its structure, closely resembling the stem or the branch from which it springs. In simple leaves, with a few exceptions, although the vascular part forms at first several fasciculi, at the base of the petiole, yet these soon coalesce into one compound fasciculus; but in compound leaves they remain distinct.

If we take a leaf of the Elder, Sambucus *nigra,* and place a transverse section of the common petiole under the microscope, we perceive ten distinct fasciculi of vessels. Five of these (*b. b. b. b. b.* fig. 11, Plate 8) are compound fas-

cicles, embedded in the cellular substance of the petiole; and five (*a. a. a. a. a.*) fasciculi of proper vessels occupying the angles of the footstalk, and situated in the bark, or at least exterior to the former and immediately within the cuticle. The compound fasciculi consist, each, of a band of spiral vessels, arranged in rays, and two fasciculi of proper vessels; one interior, and the other exterior to the band of spirals, but both tangent upon it. One of these compound fascicles passes into each leaflet; and consequently their number, in the common petiole of compound leaves, generally corresponds to that of the leaflets. In compound leaves, however, which have moveable articulations, we perceive that all the separate fasciculi are collected into one fasciculus in the articulations. Thus, in the common Kidney-bean, Phaseolus *vulgaris*, the petiole of which is channelled, with an articulation at the base of the common petiole and, also, at that of each partial petiole, we find that the vascular fasciculi (*a.a.b.b.* fig. 8, Plate 10) are distinct, and form a circle situated immediately under the bark in the channelled parts of the petiole; with a considerable portion of lax cellular substance or medulla (*c.*), enclosed within the circle which they form: whereas, in the articulated parts, there is one central fasciculus only (*a.* fig. 7, Plate 10), surrounded by a large mass (*b.*) of very firm cellular matter. The advantage of this change of

disposition of the vascular bundles, in the articulations, is very obvious: for, had the fascicles remained distinct, and surrounding the pith, in the articulations, those on the outside of the flexure, in every considerable motion of the joint, must have described so large a circle, as would have endangered the organization of the vessels by the extension; while those on the inner side would have suffered, equally, by the compression to which they must necessarily have been subjected. But, by the whole of the vessels being situated in the centre of the petiole, the extension and compression produced by the flexure, on every part of the fascicle, is not more than can be borne by any individual vessel, whether spiral or entire; and, thence, the freest and most varied motion of the joint can be exercised with impunity. The necessity of such a modification of structure, in the petioles of compound leaves, susceptible of motion, may indeed be inferred from the fact, that articulations are present in all those which perform certain movements; as, for example, those which fold together their leaflets at night; those which are endowed with the power of spontaneously moving their leaflets, as Hedysarum *gyrans;* and those which fold their leaflets together when touched, as Mimosa *sensitiva* and *pudica.*

Some simple leaves, those for instance of the Holly Hock, of the Geranium tribe, &c. which have several principal costæ diverging from

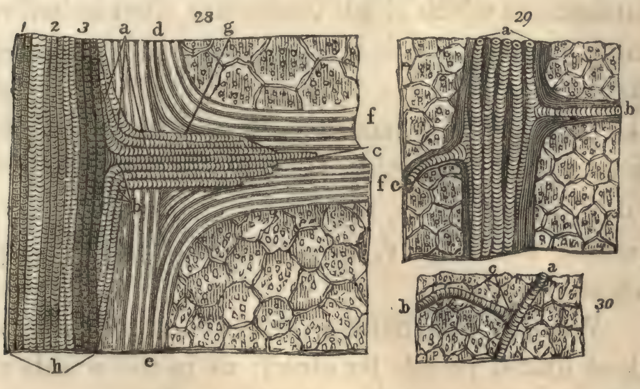
the summit of the petiole, and in this respect have an affinity to digitate leaves, present nearly the same vascular structure of the petiole as the compound leaves. The fasciculi are distinct; and correspond in number to the principal costæ of the leaf; each of which may be thus regarded as a kind of midrib, and the leaf as composed of a number of conjoined leaflets: so that these leaves, although they are necessarily classed as simple leaves from their external appearance, yet, bear in anatomical structure the same affinity to digitate compound leaves, which the webbed foot of a bird bears to one which is not webbed. A similar structure, also, is found in the petioles of those leaves which are longitudinally ribbed, or nerved as the common expression is, from the base of the expansion, as for instance those of the genus *Melastoma;* but, when the ribs do not originate from the base, although they are very conspicuous, as, for example, in the leaf of the Cinnamon tree, the structure of the vascular system of the petiole is exactly the same as in simple dicotyledonous leaves, which are not longitudinally ribbed.

If, instead of a transverse section, we place a longitudinal section of any of these leaves under the microscope, we perceive that each fasciculus is composed of spiral and proper vessels, the same as we have already seen constitute the ribs in the leaves of monocotyledons.

Tracing the vascular fasciculi from the petiole into the expansion, in the thin, simple leaves of dicotyledons, we find their divisions, subdivisions, and ultimate ramifications much more diversified and minute than in the leaves of monocotyledons. Whatever may be the origin of these divisions and subdivisions, whether they proceed from one central fasciculus, or from several longitudinal costæ, the ramifications become smaller and smaller, owing to a diminution of the number of the vessels which they contain; but not owing to any diminution of the diameter of the vessels themselves: for, although a principal fasciculus may contain larger and smaller spiral vessels, yet the general comparative magnitude of the vessels, in the smallest fasciculus, is the same as in the largest. This question, therefore, again presents itself: Do the vessels of the leaf inosculate and anastomose, or are the smaller fasciculi merely separations from the larger?

Dr. Grew, as I have already stated, denied that they ever inosculate or anastomose until they arrive at their final distribution. In appealing to nature for a solution of this disputed point, we find Grew's opinion so far correct, that the vascular fasciculi of the costæ, which are given off from the midrib, are separations from the petiolar fasciculi in their progress towards the apex of the leaf; and that the fasciculi forming some of the secondary

costæ, also, are separated in a similar manner. But in the smaller ramifications, we perceive that many of the fasciculi are connected with each other at nearly right angles; and in these instances the vessels are not separations from the larger fasciculi, but are distinct and merely applied in a peculiar manner to the sides of those from which they seem to arise; as can be readily demonstrated by dissection, with the aid of the microscope. In this minute portion of a leaf of the Lilac, sliced from between the cuticles, and examined, by transmitted light, under a very high magnifying power, we observe that, in the smaller fasciculus (*g*. 28.), which is composed of seven spiral




vessels, and united nearly at a right angle with the larger fasciculus (*h*.), three of the vessels (*a*.) form a curve upwards, and three (*b*.) a curve downwards, before they unite with the

larger fasciculus; while the central vessel (*c.*) seems to terminate in a straight line on the side of the vessel 3, which is one of those composing the larger fasciculus. In this case it is evident that the smaller fasciculus is not a separation from the larger; but is joined to it by a species of anastomosis; which, in the central vessel, is effected in a direct manner by the application of its extremity to the side of the vessel on which it terminates; and, in the other six vessels, in a less direct manner by the lateral application of a portion near the extremity of each vessel, before it curves outwards to the particular vessel on which it terminates. In other leaves, as in those of the garden Lettuce for instance, in which single vessels are often united to large fasciculi (*a. b. c.* 29. page 581) and to other single vessels (*a. b. c.* 30. page 581), the nature of the first species of anastomosis, just described, is still more perceptible. One of these examples (28.) demonstrates, also, that the proper or returning vessels (*d. e. f. f.*) unite in the same manner as the spiral.

Whether the communication of the cavities of these united vessels be direct, as in the vessels of animals, so as to allow the fluids they convey to flow in an uninterrupted stream from the one to the other, I have not been able to determine. It is, however, evident that in the leaves of dicotyledons, as in those of monocotyledons, all the vascu-

lar ramifications of the foliar expansion are not prolongations of the vessels forming the petiolar fasciculi; but that many of them are distinct vessels anastomosing with others, although in a different manner from this kind of union as it occurs in vessels in animal bodies. It is probable that the inosculation which occurs in the proper or returning vessels, more nearly resembles that which we find in vessels of animals; for, as the proper vessels are simple membranous tubes, any communication between them must be by direct openings, such as are found to exist in the vessels of Marchantia (see page 550).

2. The *thick* and *fleshy* leaves of dicotyledonous plants are seldom petiolated; but when they are so, the arrangement of the vascular fasciculi, both in the petiole and in the expansion, closely resembles that of the thin membranaceous leaves. The sessile leaves of this division are generally thicker and more succulent than the petiolated. If we take the genus Mesembryanthemum, as affording specimens illustrative of the character of these sessile leaves, we find that the vessels pass from the stem into the leaf in one or more fasciculi, according to the figures of the leaves. Thus in the Hatchet-leaved Mesembryanthemum (M. *Dolabriforme)*, the leaves of which are connate, the sap-vessels enter the leaf in one bundle, which extends in the direction of its

axis, the whole length of the leaf, giving off in its course a few thread-like branches only at considerable intervals; and as this vascular fasciculus and its ramifications are situated in what may be termed the pith of the leaf, and are, consequently, imperceptible on its surface; this description of leaves appears to the unassisted eye destitute of vessels. These organs are, indeed, comparatively few in succulent leaves; and are less necessary than in membranaceous leaves; for, as succulent leaves either exhale very little moisture, or absorb a considerable quantity from the atmosphere by their surfaces, the nutriment of the plant, in the first case, is sufficient although the fluids taken up by the roots be comparatively scanty; and, in the second, it is supplied, independent of that which may be furnished by the roots, by cutaneous absorption. In the leaves of the broad-leaved species of Mesembryanthemum, and in similar succulent leaves, the vessels enter the leaf in several distinct fasciculi; which diverging, pass on in nearly straight lines, giving off a few bundles only in their course; but as they approach the apex of the leaf, whatever its form may be, they divide, subdivide, and inosculate as in thin leaves; and the proper or returning vessels accompany and surround the spirals in all their divisions. In the succulent leaves of dicotyledonous plants, also, we find the same system of tubular cells, between the

pulp and the cuticle, which we described in the Aloe (page 564); and in the leaf of the Mesembryanthemum, under examination, we perceive these tubes commencing immediately under the cutis, and terminating generally in the cells of the central pulp; but sometimes in follicles, which are both very irregular in form, and of very different dimensions. It is probable that part of the fluid taken up from the atmosphere passes at once into the central cells, the contents of which are colourless, while another part remains in the tubular cells, and undergoes that change, which is the usual result of the agency of light on the juices of all leaves exposed to its influence. The green colour of the fluids contained in these cells, marks out their limits, in a transverse section of the leaf, even to the naked eye.

The structure of the vessels in succulent dicotyledonous leaves is the same as in all other leaves. The conducting vessels are spiral tubes, of the same diameter at the apex as at the base of the leaf; and the proper or returning vessels are membranous, and apparently perforated, although their transparency renders it difficult to determine their real character. The ramifications are all given off at acute angles; and appear to be merely separations from the caulinar or petiolar cluster, as Dr. Grew supposed was the case in all leaves; at least

they do not anastomose until, as I have already stated, they approach the apex of the leaf.

In this view of the arrangement and structure of the vascular system of the leaf, I have not noticed those cutaneous vessels which Hedwig has described as lymphatics; but the existence of which has been denied by Mirbel and others. If we admit their existence, these vessels must undoubtedly be regarded as forming a part of the vascular system of the leaf, and ought now to be described; but as this involves a knowledge of the entire cuticular system, the consideration of this point must be deferred until we examine that system.

II. *Cellular system of the leaf.* On cutting a thick, succulent leaf transversely, we immediately perceive that it consists chiefly of a pulp; which, when placed under the microscope, or examined by a good magnifying glass, is evidently composed of cellular tissue. Extending our inquiries, we find that this substance forms a large part of the structure of leaves; filling up the meshes of the network formed by the vessels in the thin and very vascular leaves; and, in all, occupying that space which separates the two cuticular layers, which constitute the upper and the under disks of the leaf.

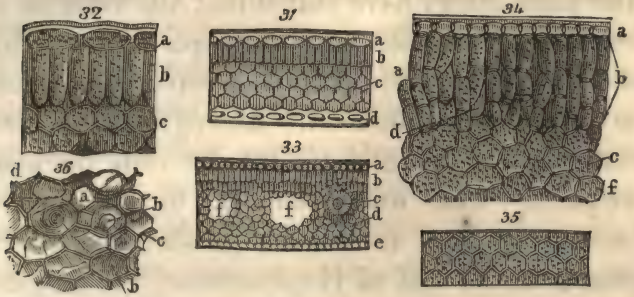
The cellular substance of leaves differs very

considerably in *density*; but this diversity depends more on the quantity and quality of the juices the cells contain, than on any diversity of structure in the cells. To the same causes, also, may be attributed, in a great degree, the *variety of figure* which these cells exhibit: for, although they are in some instances globular, or nearly so; and in others triangular; or more or less regularly hexagonal; yet, it is probable, that the majority are originally spheroidal vesicles; and that the variations from this figure depend on the turgescence of the vesicles, and the consequent compression which must necessarily result from their contiguity. The hexagonal figure being that which spheroidal vesicles, mutually comprising one another, are naturally disposed to assume, we find that a more or less regular hexagon is the most common form of these cells; and this figure is generally more regular in the cells forming the centre of the substance of the leaf, owing to these being there more distended with fluid, than in those towards either of the cuticles.

But that the diversity of figure in the cells of leaves does not, altogether, depend on mechanical compression, is evident from the fact, that those towards the upper disk of the leaf often differ in form from those towards the under disk; and yet in both these situations we may suppose the compression to be nearly equal.

This difference, as shall afterwards be explained, is probably necessary for the distinct functions of these two surfaces; and thence, in every attempt to theorize on the structure of parts, the propriety of keeping in view the fact, that plants as well as animals are living beings, and consequently not regulated by those laws which control the configuration of inanimate matter. No plant is better adapted than the Christmas Rose, Helleborus *niger*, to demonstrate this diversity of cellular structure in the same leaf. If we examine a thin transverse slice of a leaf of this species of Hellebore, with a good magnifying glass, we perceive that, immediately under the cells of the cutis (31. *a.*), which are large and oval, there is a range of *tubular* cells (*b.*) terminating in the true pulp or parenchyma of the leaf (*c.*); which consists of irregular hexagonal cells, and occupies the whole of the space between the tubular cells and the cuticle (*d.*) of the under disk of the leaf. Under the highest power of the microscope, we find that these tubular cells (32. *b.*) have apparently a direct communication with the cells (*a.*) of the cutis; and also with the range of cells (*c.*) immediately beneath them: but in neither are the mouths open, for, a membrane bounds the oblong cell in every direction. In the transverse section of some leaves, as for instance those of Calla *Æthiopica* (33.), which is an aquatic

plant, we find several ranges of *tubular* cells (*b.*) commencing under the cutis (*a.*) of the su-




perior disk. Some of these terminate in the hexagonal cells (*d.*), and others in empty cavities (*f.f.*), such as are present in the leaves and the petioles of all aquatic plants, and which, being filled with air, seem intended for enabling them to rise above or to float on the surface of the water. Under the microscope these tubular cells (34. *b.*) in the leaves of Calla, resemble a chain of short vessels, with valvular partitions; and were, indeed, erroneously regarded as such by Malpighi and Leuwenhoek, who observed them in the stem. But these cells are not furnished with open mouths, nor with valves, neither where they originate in the cuticular cells (34. *a.*), nor at their union with each other, nor where they terminate (*d.*) in the common pulp of the leaf; and this is the case, also, in all leaves furnished with tubular cells. When the tubular cells are cut transversely, they appear to be of an hexagonal

figure (35.), and not round, as might be suspected from their longitudinal aspect. Sprengel and some others have stated that the cells in all leaves are elongated near the upper surface; but the simple inspection of many leaves is sufficient to refute this statement. Among the succulent leaves, even, in which the tubular cells are more frequently met with than in membranaceous leaves, they are not always present; as, for instance, in the leaf of Hoya *carnosa*, the only difference between the upper and under disk of which is in the structure of the cutis, which on the superior surface (*a*. fig. 16, Plate 10) is a simple transparent pellicle, while on the inferior *(b. ibid.)* it is cellular; and in the cells near the upper disk being filled with a greener and more opaque juice than those near the under disk.

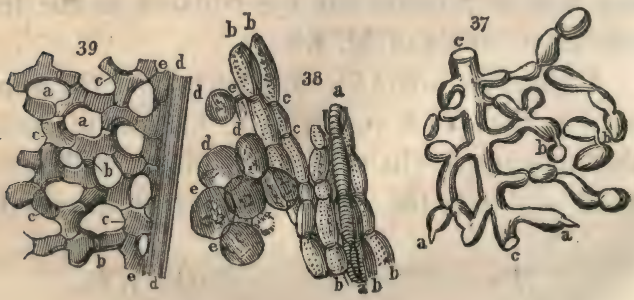
With regard to the individual structure of the cells constituting the parenchyma of leaves, we find it is the same as that of the cells in the other parts of the plant. Each cell appears to be a distinct, transparent, membranous vesicle, formed into the figure it displays by the pressure of the contiguous cells, and thence, the partition separating each cell, must be a double membrane. This is more evident in the microscopic examination of the cellular substance of some leaves than of others; thus, in this minute portion (36. page

589), taken from the leaf of Iris *Germanica*, we perceive that not only the cut edges (*c.*) of the cells appear double; but that where some of the cells deviate from the hexagonal figure, there are evident interstitial spaces (*a. d.*) between them, which if the cells were not distinct vesicles would not occur. These interstices have been noticed by Leuwenhoek, Treviranus, Comparetti, and M. Kieser; the last of whom supposes them to exist at every angle of every cell, and by their conjunction to form canals which surround it; and to be the only passages by which the fluids are conveyed through the cellular substance*. It is unnecessary to point out the improbability of this opinion; and it is sufficient for our purpose to demonstrate the existence of these interstices, to prove the double nature of the intercellular partitions. This is very evident in the elongated cells, which we have seen exist near the upper disk of many leaves; and in the spaces formed by the conjunction of these only, have I been able to perceive any resemblance to the intercellular canals of M. Kieser.

A question arises in consequence of the supposition that each vesicle is a distinct sac:—in what manner do the cells communicate with each other, and with the vessels which they surround?

* *Mém. sur l'Organisation des Plantes*, p. 20.

Malpighi, aware of the necessity of an explanation of this point, maintains that a small tubular production (*a. a.* 37.) issues from each cell or vesicle, by which it communicates with the contiguous cells (*b. b.*), and with the vascular system of the leaf (*c. c.*); and has given a microscopic representation of this cellular structure in the *Cactus* (37.) to illustrate his position. A similar idea was entertained, also, by M. de Saussure, who describes the cellular part of the leaf as a congeries of minute transparent vessels, which are so dilated between their junctions as to assume the appearance of cells or vesicles. But, notwithstanding the high authority advancing this opinion, my observations prevent me from according with it: since in no leaf, which I have examined, have I been able to detect these communications. In the Cactus, if we select a small portion of a vessel with some cellular matter adhering to it, as in the minute morsel (38.), under the microscope, before us, we perceive that the cells (*b. b. b.*) are



in close contact with the vessel (*a. a.*), but neither spring out of it, nor appear to have any direct communication with it; and that neither the elongated cells (*b.b.b.b.b.*), nor the spheroidal (*d.d.d.*), appear to communicate with one another by any tubular production. The transparency of the cellular membrane produces an appearance (*c. c. e. e. e*) at the points of contact of the cells, which might be mistaken for small tubes, but which arises from the impression of the contiguous cells upon one another. Even in that peculiar modification of the cellular structure, which is found immediately within the cutis of the inferior disk of some leaves; and in which the cells assume the appearance of anastomosing tubes (39.), none of the tubular connecting processes, described by Malpighi, are perceived; nor do these cells appear to communicate directly with the vessels which they surround. As this is the most curious modification of the cellular structure of leaves, I shall demonstrate it to you as it appears in the floral leaf of Helleborus *viridis*, which I select for this purpose, from its being almost devoid of colour. In the minute portion before us, as it appears under the microscope, we perceive the range of cells *e. e.* (39) closely applied to the proper vessels *d. d.* but not communicating with it: the cells *c. c. c. c.* assume various forms, but all are apparently tubular; and, where they are more transparent than common, we dis-

tinctly perceive the nature of their conjunction (*b. b.*); but no projecting tubular processes. The spaces, such as *a. a.* are filled with air in the same manner as the vacuities in the leaves of aquatic plants. In what manner then do the cells communicate? To answer this question properly, we ought to understand the structure of the intercellular membrane. But here our instruments fail, if they do not mislead us; and, under glasses of the highest power, this membrane appears different under different circumstances: by transmitted light, it seems a simple, unorganized, transparent pellicle; but, by reflected light, is evidently porous. I have already stated my belief that the cells of the stem communicate by pores, and I see no reason for altering this opinion with regard to those of the leaf: although I do not concur in opinion with M. Mirbel and Sprengel, that the form, position, magnitude, and number of these pores can be determined. An opinion has been advanced, that the fluids may be transmitted from cell to cell, "consistently with the integrity of the cellular structure," by the exercise of the alternate functions of secretion and absorption;" but these functions imply the existence of either glands or vessels connected with the absorbing and secreting surface, which are, however, even less demonstrable than the pores. Upon the whole, the question is still unanswered; and all

that we certainly know of the subject is, that the fluids are transmitted from cell to cell, through every part of the vegetable system, although the structure by which this is accomplished remains undiscovered.

Whatever may be the mode in which the cells communicate with one another, their contents are more or less fluid or solid, according to their situation in the thickness of the leaf. Thus, in thin leaves the cells near the inferior disk are more transparent, owing to their contents being more fluid than those near the upper disk; but in both we perceive a number of granules, which are more opaque and of a deeper green, as the cells containing them approach the upper disk. In succulent leaves, and those which maintain a vertical position, the opacity and green colour of the granules, are the same towards every face of the leaf; but they are generally colourless in its centre. In the cells, also, of some leaves, regular crystallized salts are found; and in others the fluids are tinged of different hues besides green; in which cases the leaves themselves display the same hues on one or both surfaces.

The *size* of the cells varies in different leaves; in some, even when examined under the most powerful glasses, they appear like the smallest vesicles; while, in others, they are so large as to be perceptible to the unassisted eye.

I have already demonstrated to you the existence of large vacuities in the foliar parenchyma of the leaves of aquatic plants. Mirbel regards these as accidental productions, rents or defects in the cellular texture; an opinion, however, which is instantly refuted on a minute examination of these parts. If we place a portion of the petiole, or any of the larger costæ of an aquatic, this thin transverse slice, for example, of the petiole of Trapa *natans* (fig. 12, Plate 10), under the microscope, we perceive that the vacuities have a symmetrical arrangement around the centre (*c.*), which is vascular and consequently more opaque than the rest of the slice; and that some of the vacuities are open (*a. a.*), while others (*b. b.*) are closed. The membrane which covers some of the vacuities as they appear in the slice (fig. 12.) before us, is a diaphragm, which, as it forms the roof of one cavity, is also the floor of another; and it is owing to these diaphragms not being all on the same plane that some of the vacuities appear devoid of them, in the transverse slice of the petiole of the leaf of any aquatic plant. The intimate structure of these diaphragms is seen in a highly magnified view of one of them, as represented at fig. 13, Plate 10; in which *b.* shows that the diaphragm consists of regular hexagonal framework, with the intervening membrane either perforated or studded with small transparent, amylaceous gra-

nules; and *a.* that the lateral partitions between the cavities, apparently consist of square cells, when transversely divided, as in the figure before us, although they are hexagonal, when viewed laterally, as in the diaphragm. Each cavity is lined on every side with a thin pellucid pellicle, closely resembling the external cuticle; and frequently hairs, knobs, and similar cuticular productions are found projecting into these cavities. Kieser, who is the only author who has noticed these bodies, remarks that he had sometimes observed, in the cavities of Calla Æthiopica, small globular, pedunculated bodies; which, springing from the sides, project towards the centre of the cavities; but, according to my observations, they are more common in those of *Typha, Equisetum,* and *Nymphæa,* in the latter of which they closely resemble the branched hairs (see Plate 9, fig. 14.), which form the tufted pubescence on the under disks of some leaves.

In closing this view of the anatomy of the cellular system of leaves, I have to remark, that although it embraces the more common varieties that are met with, yet it is probable that, in the vast range of the vegetable kingdom, many other diversities of structure of the cellular matter exist.

From these inquiries into the structure of the *vascular* and *cellular* systems of leaves, the affinity which exists between the stem and the leaf is very

obvious. In the stems of monocotyledons, the vessels run nearly in straight lines in distinct fasciculi, embedded in a cellular pulp; and a similar vascular arrangement presents itself in the leaves of this tribe of plants. In dicotyledons, on the other hand, the vascular fasciculi of the stem are not distinct, but form a reticular tissue which covers the whole circle of the stem; and, in like manner, in the leaves, the vessels ramify in every direction, forming a most complicated and beautiful network, the interstices of which are filled with the cellular pulp. The leaf, therefore, may be regarded, in some respects, as a mere expansion of the stem; and, consequently, in aphyllous plants, we perceive that the stem is adapted to perform all the functions of the leaf. The internal structure of the floral leaves or *bracteæ*, and of those more temporary foliar appendages, which are termed *stipulæ*, is nearly the same as that of the real leaf; even the scales that envelop buds, and which are always described as deriving their origin from the cortical part only of the stem, and consisting chiefly of cellular matter, have in every respect the same structure as leaves, as far, at least, as relates to their vascular and cellular systems.

# LECTURE XI.

OF THE CUTICULAR SYSTEM OF LEAVES:—USE OF THE CUTICULAR APERTURES.—OF THE APPENDAGES OF THE STEM AND LEAVES—PUBESCENCE—THORNS—PRICKLES—GLANDS—PROPS:—USES OF THESE APPENDAGES.

Every leaf is covered with a real skin or epidermis, which not only guards the vascular and the cellular matter from external injury; but is the medium by which it performs the important functions of absorption and exhalation. In the majority of leaves, the epidermis can be separated from the parts it covers: and appears to be a compound organ, or to consist of two distinct layers; the exterior of which is a fine, transparent, apparently unorganized pellicle, and the interior vascular and cellular. But the opinions and descriptions of phytologists are at variance on this subject. Grew *, Malpighi †, Du Hamel ‡, Desfontaines §, Mr. Keith ||, M. Kieser ¶, M. Mirbel **,

* *Anat. of Plants*, p. 62.

† *Anat. Plantarum*, p. 2—12.

‡ *Phys. des Arbres*, i. 8.

§ *Mém. de l'Inst. Nat.* i. 481.

|| *Syst. of Phys. Bot.* i. p. 313.

¶ *Mém. sur l'Organ. des Plantes*, p. 141.

** *Elem. de Phys. vég.* i. 36.

and some others, have described the cuticular covering of leaves as a simple body; while M. de Saussure*, Mr. Francis Bauer†, and M. Decandolle‡, concur in the opinion which I maintain of its compound nature. Let us examine the proofs upon which this is founded.

The true epidermis, or the delicate pellicle which forms the outermost covering of the leaf, can be readily demonstrated in any small portion of the cuticular covering carefully raised by the point of a lancet, and placed in a drop of water under a powerful microscope. In this small portion, taken from a leaf of Dianthus *Caryophyllus*, it is seen (*a*. 40. page 602) extending beyond the area of the meshes (*b. b.*) of the interior cuticular layer, which are seen through it, and is evidently a simple pellicle. But Mr. Keith§, who admits that it may be seen in this manner, supposes that its individuality is not proved by such a demonstration, as the meshes, the intervals of which it might originally have filled up, may be accidentally obliterated; but, although there is some plausibility in this objection, yet, when we take this appearance in conjunction with the double character observed in the transverse section of the cuticular covering of every

* *Encyclop. Method.* i. 67.

† *Tracts relative to Botany.*

‡ *Mém. de l'Inst. Nat.* i. 351.

§ *Syst. of Physiol. Bot.* vol. i. p. 313.

leaf which we have examined, there is sufficient reason for believing that it is as much a distinct layer as the cuticle in the human body, although, in the leaf, it cannot be readily detached from the interior layer of cutis. It is described by Saussure as being perforated by the slits or pores which, I shall soon demonstrate to you, are found on one or both of the surfaces of every leaf; but we shall find, on minutely examining these, that it is not perforated by them, but enters into them, as well as into every gland opening on the surface of a leaf, as a lining membrane; and is, in fact, the covering of every part of the vegetable texture, which would otherwise come in contact with the air. If, however, it cover every part of the surface of the leaf, and is an imperforated membrane, by what means, it may be asked, does the fluid which exhales so freely from the leaves escape? It is certainly not easy to answer this question; but as we can scarcely form an idea of a membrane perfectly free from pores, even in a living body, transmitting fluids; we may conclude that, although no pores are visible in this membrane, even when it is examined under the microscope, yet, it does not follow that no pores exist; and, in accounting for the transudation of the fluids, which the leaf throws off, we must always bear in mind, that the functions of living bodies are influenced by different powers from

those which regulate the operations connected with inert matter.

The second or *interior cuticular* layer is seen through the epidermis, and consists of a vascular network resting upon a layer or layers * of cells.

Taking the same portion of the cutis of Dianthus *Caryophyllus* (40.) to demonstrate the superficial structure of this layer; we find that, except within the boundary of the detached epidermis (*a. a.*), the whole is spread with a network of irregular hexagons formed by lines which appear double, and terminate in a ring surrounding a slit or oblong pore (*c. c.*), which occupies the centre of one of the longest bounding lines of almost every alternate hexagon. The same appearance of the interior layer of cutis is seen on both surfaces of the leaf of Dianthus; but, as I shall afterwards demonstrate, this is not the case in the majority of leaves †. If we now place a very thin transverse

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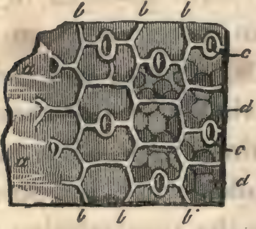


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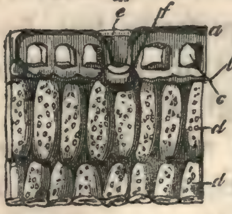


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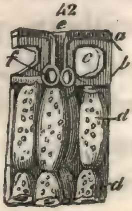


* Mr. F. Bauer describes the cuticle of a species of Hæmanthus as composed of several layers of cells. See *Tracts relative to Botany*. Lond. 1805.

† In Plate 10, figure 3 represents a portion of cuticle

slice of the leaf of Dianthus under the microscope, to examine this layer in its thickness, we can readily distinguish it (*b.* 41.), by the form of its cells (*c.*) from the parenchyma (*d. d.*) upon which it rests; and, also, from the epidermis (*a.*) which covers it; for, in this leaf, the cells of the parenchyma assume an oblong form immediately under the cutis, whereas the cells of the cutis are irregular spheroids, and the simple layer of epidermis is remarkably distinct.

Whether these cuticular cells have any direct communication with the oblong cells beneath them, I have not been able to determine; but in separating the cutis, by tearing, some of the oblong cells always adhere to it; and, when viewed through it, by transmitted light, appear like a smaller cuticular network (*d. d.* 40.), filling up the larger meshes. These might be mistaken for the cuticular cells; but the transparency of the cutis prevents its cells (*e.* 41.) from being visible in a superficial view of the organ. In this transverse section of the leaf of Dianthus (41.) the distinct nature of the epidermis (*a.*) is perfectly evident, both as a covering to the true cutis (*b.*) and as lining the slits (*e.*), one of which is here divided lengthways.

taken from the under disk of the leaf of Hoya *carnosa;* and figure 4, a portion from the upper disk of the same leaf. Both are magnified about 300 times.

The *lines* forming the meshes which thus characterize the cutis of leaves, were first described by Hedwig as vessels, originating in the circumference of the pores; an opinion which is supported by the elder M. De Saussure and M. Kieser; and which is confirmed by the microscopical examination of a portion of the cutis of any leaf. Remarking the facility with which this part of the cuticular structure can be demonstrated, our surprise is excited that Sprengel, Link, Mirbel, Jurine, Krocker, and others, should have advanced the opinion, that these reticulations form no part of the real structure of the cutis, but are merely the adherent fragments of the sides of the subjacent cells: for, as I have already demonstrated, the parenchymal cells are much smaller than the cuticular meshes; and, when the cutis is sufficiently transparent, they are seen through it very distinctly (40. *b. b.*), but not at all coinciding with the sides of these meshes. Admitting, therefore, that these lines are lymphatic vessels, it is not improbable, as M. Kieser has asserted, that they terminate by one extremity in the larger vascular fasciculi; but on this point I have not been able to satisfy myself. The meshes, which they form, differ very much, both in form and size, in different leaves*. In al-

* Mirbel, reasoning from the false opinion which he had formed of the structure of the cutis, observes, " les différences

most all the monocotyledons, in the Grasses, and in every plant the leaves of which have parallel costæ, the meshes are nearly irregular parallelograms; but, in forming these, the vessels sometimes run in straight lines, as in common Meadow grass, Poa *trivialis* (45.); sometimes in slightly undulated lines, as in the White Lily, Lilium *candidum* (44.); and sometimes zig-zag, as in Indian Corn, Zea *Mays* (fig. 14, Plate 10). In some of the fleshy leaves they are nearly regular hexagons, as on the upper disk of Hoya *carnosa* (fig. 4, Plate 10), and on both surfaces of the leaves of Aloe *verrucosa* (43.): but, in the majority of dicotyledons, they assume very irregular figures †.

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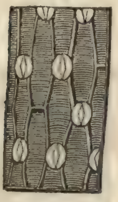

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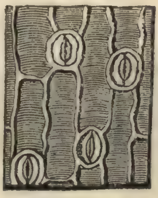

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" qu'elle présente viennent de la forme des cellules dont elle " faisait partie."—" Les parois cellulaires restant attachées à " l'épiderme, y dessinent de petits compartimens dont la forme " indique celle du tissu cellulaire lui-même. Tantôt ce sont des " parallélogrammes plus ou moins réguliers, tantôt des hex- " agones, tantôt des polygones divers, dont les côtés sont on- " dules." *Elem. de Phys. vég.* 1 partie, p. 36.

† This irregularity is well exemplified in common Sorrel, Rumex *acetosa*. In Plate 10, fig. 9 represents a minute portion

Whatever may be the figures which they present in the cutis covering the spaces between the vascular ramifications of the leaf, they invariably appear as irregular parallelograms (46. *a. a.*) * in that which covers the vascular fasciculi; a fact which gives some support to the opinion of M. Kieser, that the vessels forming the meshes terminate in these fasciculi. The difference in the size of the meshes, in different leaves, is still more striking than in their forms; but in all they are very minute. On a portion of the cutis of Aloe *verrucosa*, $\frac{1}{576}$ of a square inch in size, I counted ninety-six meshes, or 55,296 to the square inch!

The form of the *cuticular cells* (41. 42. *c.* page 602), owing to the cutis being more transparent

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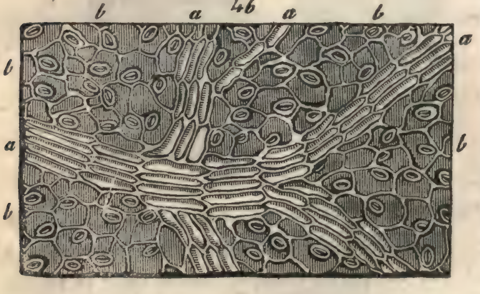


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of the cutis taken from the upper disk of a leaf of that plant; and fig. 10, a portion from the under disk.

* This represents a very minute portion of cutis taken from the under disk of a leaf of Gardenia *latifolia*, magnified 300 times, and viewed by transmitted light.

than the epidermis which covers it, can be demonstrated only as they appear in a vertical section. They are either spheroidal or oval; and are found generally empty, or filled with a colourless fluid. I have not been able to detect any immediate communication between them and the cells of the parenchyma, or even between one and another. In the greater number of leaves the cutis contains one layer only of cells; but it may contain several layers, as Mr. Francis Bauer * has demonstrated is the case in the genus Hæmanthus; and I have found that this is the case, also, in the leaf of common Oleander, Nerium *Oleander*.

The *slits* or *apertures* which have been already noticed as existing on one or both surfaces of all leaves, were first described by Grew as orifices; but afterwards regarded by the elder M. De Saussure as glands, and by M. Von Gleichen, who examined them in the leaves of Polypody, as the anthers of the Fern tribe. The more correct observations of Hedwig and of Decandolle, however, have confirmed the opinion of Grew; and, indeed, it is only necessary to examine them, under a good microscope, to be satisfied that they are real pores †. In the leaves of trees and of some other

* *Tracts relative to Botany, Lond.* 1805.

† It is extraordinary that Senebier, who searched for these apertures in the leaves of a great variety of plants, never could detect them. Vide *Phys. vég.* i. p. 456.

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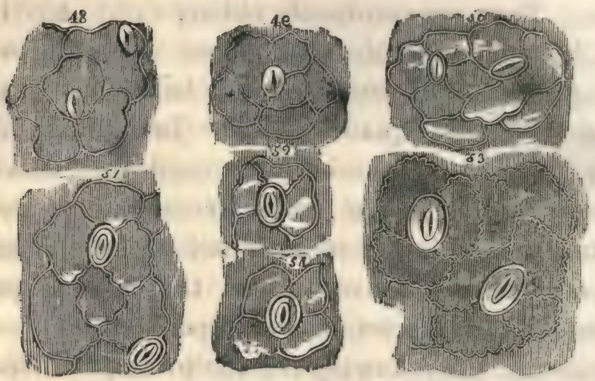
plants, they are observed on the inferior disk only; but in others, particularly in the Grasses, the Coronariæ, and the Palms, they occupy both surfaces. Some Phytologists have asserted that the lower tribes of plants are destitute of pores; but this statement is incorrect, as they are easily demonstrated in *Marchantia* and a few of the Mosses. Plants which have no leaves, such as the Cactus tribe and many of the Rushes, and some of those, also, which have leaves, as the Grasses, have pores on the stem; but in general they are confined to the leaves. Those leaves, however, of aquatic plants which are constantly under water are destitute of pores; the upper disk only of leaves which float on the surface of water possess them; and when a land plant is made to grow under water, the new leaves, which are evolved under the water, have no pores, although those which they have succeeded, or the aërial leaves, were furnished with them. Even in plants which are partly emersed and partly submersed, as for instance Ranunculus *aquaticus*, the leaves that grow under the water are destitute of pores, while those which float, or are above that fluid, are provided with them. It has, also, been asserted that etiolated leaves, or such as are excluded from the light, are destitute of pores; but there is some inaccuracy in this remark, as I have found them as numerous on the interior etiolated, as on

the exterior green leaves of the common Cabbage and the Lettuce.

These foliar apertures vary very considerably in *form, size, number*, and *position*, in different leaves. They are commonly oblong (46.), but in some instances circular (47.), and in the Agave tribe (59. p. 611), and a few other families of plants, they are quadrilateral. In almost all leaves they are surrounded by a border, in which the vessels forming the cuticular meshes appear to terminate. Placing minute portions of the cuticle of different leaves under the microscope, we can readily ascertain the superficial form of these pores: the following are the principal diversities of form which I have observed *. 1. A simple slit, more open in the middle than at either end, bisecting an oval shield; which may, therefore, be termed the *oval scutiform aperture, osculum scutiforme ovatum*, as exemplified on the lower disk of the leaves of Sage (48. p. 610), of Lactuca *quercina* (49.), Dandelion, Leontodon *Taraxacum*, Sweet-scented Coltsfoot, Tussilago *fragrans*, many of the Grasses, the common Bean, Vicia *Faba*, &c. 2. A simple slit, bisecting an oval shield enclosed

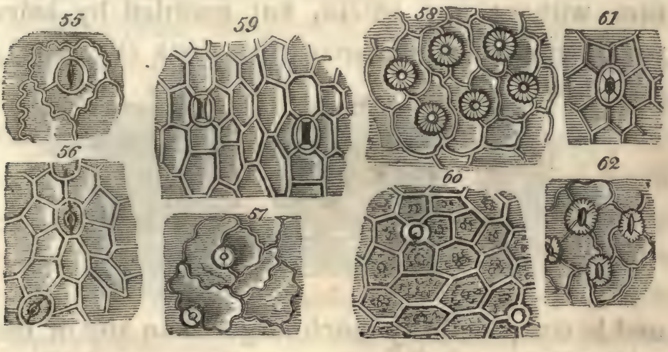
* In naming the different kinds of pores, I have assumed the fact, that they are respiratory organs, or apertures resembling in their functions the spiracula of insects; but, on account of the simplicity of their structure, I have preferred the term osculum to that of spiraculum.

within a ring, which I name the *annulated scutiform aperture, osculum scutiforme annulare,* as seen on the inferior disk of the leaves of Helleborus *fœtidus* (51.), the Violet tribe (52.), the




Coffee plant, Coffea *Arabica* (53.), the White Lily, Lilium *candidum* (44. p. 605), Gardenia *latifolia* (46. p. 606) ; the common Cabbage, Brassica *oleracea ;* the outside of the tubular leaf of Saracenia (54.), &c. 3. An open slit, or an oblong pore, enclosed by a simple oval ring, which may thence be termed the *annulated aperture, osculum annulare;* as on the inferior disk of the leaf of Hibbertia *scandens* (50.), Ivy, Hedera *Helix* (55.), Jacquinia *ruscifolia* (56.), Dianthus *Caryophyllus* (40. p. 602), Laurus *Canariensis,* Wolfsbane, Aconitum *neomontanum,* Privet, Ligustrum *vulgare,* &c. 4. A circular pore in the centre of a circular shield, which we may name the *circular aperture, osculum circulare ;* as on the inferior

disk of the leaf of common Sorrel, Rumex *acetosa* (*a. b.* fig. 10. Plate 10), of the Primrose, Primula (57.), and, very beautiful, on both surfaces of Cactus *opuntia* (58.). 5. A quadrilateral pore, *osculum quadrilaterale,* surrounded by an elevated margin, as on both surfaces of the leaves of Agave *Americana* (59.), and of all the other species of the succulent tribe to which it belongs. I cannot avoid remarking, in this place, the natural separation, which may be traced by the form of these apertures, between the Aloes and the Agaves. In the former the pores are always circular (60.), and in the latter they are invariably quadrilateral (59.).




It is impossible to notice all the modifications of these different species of the cuticular aperture; I shall, therefore, only remark, that among the varieties of the annulated aperture, we sometimes find the space between the pore, or the shield and the enclosing ring, divided into distinct por-

tions; and occasionally a double ring, with the intervening space, also, divided into four or more equal parts: examples of the first variety are found on the lower disk of the leaves of Lilac (61. p. 611), of Acuba *Japonica* (62.), Cussonia *thyrsiflora* (63.), Hoya *carnosa* (fig. 3, Plate 10); and on the upper disk of the leaf of Rumex *acetosa* (fig. 9, Plate 10). The upper disk of the leaves of Viola *odorata* affords an excellent illustration of the double ring (64.). But the most remarkable form of the cuticular pore, which I have yet observed, is found on the back of the leaves of common Oleander, Nerium *Oleander*. It appears, on a superficial view, a simple oval aperture without any shield, but guarded by hairs which cross it in different directions (65. *a. b.*);

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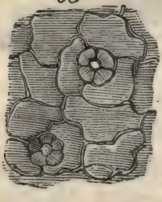

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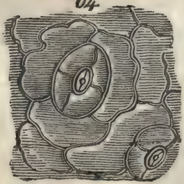

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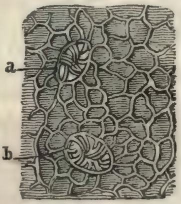


and is comparatively much larger than any of the other kinds of pores.

Some writers have ventured to assert, that no apertures are found in those plants which are generally regarded as composed almost entirely of cellular matter, among which Marchantia is usually reckoned; but the incorrectness of this opinion can be easily proved, by placing a small

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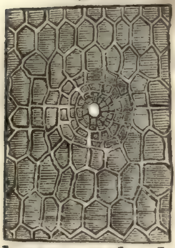


slice of the cutis of Marchantia under the microscope. The apertures are oval, and placed in the centre of a slight elevation, as represented in the marginal cut (*).

In respect of *size*, pores differ considerably in different plants; but on the leaves of the same plant their size is nearly uniform. The largest, as far as my observations extend, are those found on the leaves of Oleander; and the smallest on those of the genus Myrteæ. Sprengel says, that in the Coronariæ "their longitudinal diameter is from $\frac{1}{12}$ to $\frac{1}{20}$ "part of a geometrical line, and their diameter, "in the cross direction, is from $\frac{1}{24}$ to $\frac{1}{40}$ part;" but in "the Myrteæ, Rosaceæ, Leguminosæ, "and Caryophylleæ, two hundred of them, at "least, might lie upon a geometrical line†."

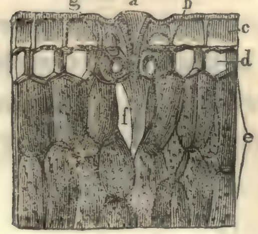
In *number* the foliar apertures vary, also, in different plants. The more minute they are, the more numerous. On the lower surface of the leaf of Gardenia *latifolia*, we find an aperture in almost every mesh; but in the Aloe tribe scarcely one pore for twenty meshes, and on the leaf of Oleander, one among sixty. With regard to *position*, these apertures are in some instances arranged in lines from the base to the apex of the leaf, and have the same

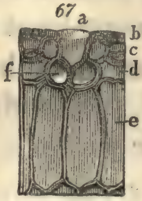
† *Elements of the Phil. of Plants, &c. by A. P. Decandolle and K. Sprengel,* § 310.

direction throughout; but in the majority of leaves they have no regular arrangement, and assume different directions. In herbaceous plants we generally find them on both surfaces of the leaves; but in ligneous plants they are scarcely ever seen on the upper surface. They are never situated on the costæ, nor on the edges of the leaf.

But these demonstrations make us acquainted with the superficial aspect only of the foliar apertures, beyond which it is surprising that no Phytologist has yet attempted to push his investigations; although it is by no means difficult to determine their structure by the aid of the microscope. Placing a very thin vertical slice of a leaf of the Clove Pink, Dianthus *Caryophyllus*, cut in the direction of the axis of the leaf, under the microscope, we find that the aperture (*e.* 41. p. 602) which is thus divided in its longitudinal diameter, is a short cylindrical tube penetrating completely through the cutis, and terminating in a cul de sac, which is impressed into a vesicle (*f.*) that appears to communicate with the oblong cells (*d.*) immediately beneath the cutis. But although the aperture penetrates the cutis, there is no opening through the epidermis (*a.*), which, on the contrary, enters into the tubular part of the pore and lines it throughout. In another slice of the same leaf, cut so as to divide one of the apertures in its cross diameter (42. p. 602), we per-

ceive that the vesicle (*f.*) appears to be double; from which it is probable that it is this vesicle, seen through the transparent substance of the cutis, which gives the appearance of the shield in the superficial view of the aperture. As we find that, in the superficial view of these apertures, the character varies considerably in different plants, so this form of the tube and the vesicle is also variously modified; but the general character is nearly the same, with a very few exceptions, throughout the vegetable kingdom, as far, at least, as my observations extend. Thus in the Agave (59. p. 611), the superficial form of the aperture is very different from that in Dianthus (40. p. 602); but if we examine it in a transverse section of the leaf, although we find the general structure of both agreeing, inasmuch as the apertures of both are lined with the epidermis, penetrate the cutis, and have at their bottom the vesicular ring; yet we perceive that that of the *Agave* differs from that of *Dianthus*, in terminating in a large dilated cell (66. *f.*), which is found always




filled with air, although it is closely surrounded by the oblong cells (*e.*) of the parenchyma, turgid with green juice. In the oblong section, also, of this aperture (67.) the vesicular ring (*f.*) does not appear to be simple as in Dianthus, but is divided by a duct, in which the aperture (*a.*) seems to terminate, and which apparently opens into the air cell (*f.* 66.); which is cut away in this section (67.).

In the leaf of Oleander the aperture (*d.* 68. p. 615) expands into a kind of sac where it penetrates into the substance of the parenchyma (*c.*); and it is throughout lined with the same kind of hairs which guard its orifice; but I have not been able to determine whether its lining membrane, which is a production of the epidermis (*a.*), be porous; although I have examined it by glasses of the highest powers. I may here remark that the section of this leaf displays an example of a cutis consisting of four layers of cells (*b.*). Decandolle considers that the cuticular apertures are connected with the ultimate ramifications of the vessels of the leaf*; and, if it be true, that the cuticular meshes are formed by lymphatic vessels, which terminate on one hand in the larger vessels of the leaf, and on the other, in the vesicular circles surrounding the fundus of the aperture, this opinion must be correct.

* *Journ. de Phys.* iii. p. 130.

The information we have thus obtained of the structure of these pores, induces me to believe that they are the respiratory organs of plants. But Phytologists have considered them intended for the functions of *absorption* and *exhalation**; and even Sprengel, who hints something regarding their analogy to the breathing spiracula of insects, rejects the idea of their being respiratory organs, because "they are not in immediate contact with the spiral vessels†." If, however, it be admitted, as I have endeavoured to prove, that the spiral vessels are not air-tubes, but sap-vessels, this objection must fall to the ground. The idea that they are *absorbing* organs, is supposed to gain support from the circumstance, first ascertained by Bonnet‡, that leaves absorb more powerfully with their lower than with their upper surface; and Sprengel remarks that " the slits are more nume-" rous in juicy plants, which are nourished more " by the surface of the leaves than by the roots**." But I reply, that although leaves absorb chiefly by their inferior surface, yet, this does not prove that these apertures are the absorbing organs; for we find none of them on the lower side of the leaves of Nymphæa and other aquatics, which

* Among those holding this opinion are MM. Bonnet, Decandolle, Sprengel, Mirbel, Mr. Ellis, and Mr. Keith.

† *Elements of the Phil. of Plants*, § 311. ** *Ibid. l. c.*

‡ *Recherches sur l' Usage des Feuilles*, p. 20.

have floating leaves; although these leaves absorb powerfully by their lower surface, and exhale by their upper, which is covered with these apertures. Decandolle and Sprengel's remarks regarding succulent and fleshy leaves, are also incorrect; for, in the genus Aloe, which is supported chiefly by absorption, the apertures are comparatively few; and the function of absorption in these plants seems to be connected with a small papilla, which rises in the centre of every mesh; and probably acts in the same manner as radicles on roots. It is still more difficult to accord with the opinion that the same foliar apertures perform such opposite functions as those of *absorption* and *exhalation;* although there is nothing incongruous in supposing that they are both exhalant and respiratory organs. That they exhale, was first rendered probable by the experiments of Treviranus, who found that plates of glass applied to the lower disks of leaves were soon covered with drops of water, while they were not at all bedewed when they were affixed to the upper disks; and Decandolle afterwards proved that the aqueous transpiration is greatest in those plants which are supplied with the greatest number of apertures. The opinion, however, still prevailed, that leaves exhale also by the upper disk, although the majority of leaves have no apertures on that disk; but before yielding implicit credence to the assertion, that these aper-

tures are the foliar exhalants, it was necessary to prove that no exhalation takes place when they are obstructed; and to determine this point I made the following experiment:—Two twigs of *Laurustine*, each having four leaves nearly of the same size, were cut from the plant, and brought to the same weight by being placed in opposite scales. The lower disks of all the leaves on one twig were next brushed over with a composition of mucilage of gum arabic and a small proportion of Tragacanth; and when this was dry, each twig was placed under a cylindrical glass jar containing air, and immersed in a saucer of water. In a short time the sides of the jar containing the twig in its natural state, were covered with drops of water; but, at the end of two days, not the smallest quantity of moisture appeared on the sides of the jar containing the twig, the apertures of the leaves of which had been obstructed by the mucilage. The conclusion to be drawn from this experiment is, that that surface only on which apertures exist exhales, and consequently that these apertures are the exhaling organs. This experiment leads us, also, to draw a conclusion from the experiments of M. Bonnet, different from that drawn from them by that author. He concluded that, because the leaves of trees which were laid with their lower disk upon water remained longer green and fresh than those which had the upper disk applied to the water, this fluid

was absorbed by the under surface; but if, by thus placing such leaves, we obstruct the exhaling pores, we can readily see why the leaves will be longer withering, since no exhalation takes place; while in those placed on the opposite disk, the exhalants are free to perform their functions, and thus empty the foliar cells of their aqueous contents more quickly than the absorbents of the upper disk can supply them. In stating this argument, I do not feel bound to point out by what media leaves absorb: although I have already hinted my opinion, that this function in the succulent plants of arid soils is performed by a distinct set of organs. A further proof of the truth of this conclusion is, that the leaves of herbs, as Bonnet himself observed, remain fresh nearly the same length of time when placed on either surface; for these apertures are present on both surfaces; and, besides, these leaves sooner wither, whichever surface is in contact with the water, than the leaves of trees which are laid with their inferior surface upon that fluid.

Were I now to enter fully into the proofs, that the foliar apertures are, also, respiratory organs, I should be anticipating the arguments which must be again detailed, when we come to the consideration of the general functions of the leaves; and, therefore, I shall at this time, as briefly as possible, examine those proofs only which are connected with the structure of these organs.

All animals that require the presence of air for their existence, have some peculiar apparatus for producing that change in the blood which has been termed its oxygenizement; and the change, so termed, is said to be the result of respiration, whether it be performed by lungs or by spiracula. Plants, also, require the presence of air; vitiating it, under certain circumstances, in the same manner as animals, but, under others, increasing the proportion of its oxygen: hence plants may properly be said to respire, and the question arises, by what organs is this function performed? Phytologists have generally agreed, that the leaves are the lungs of plants; but still it may be inquired, does the whole of the leaf act, or in what part of it are the respiratory organs situated? My answer is, that the foliar apertures are the actual breathing organs of the plant. In support of this position I refer to the situation of these apertures, which are never seen on leaves that are not exposed to the air; for the leaves of submersed aquatics are devoid of them; even the leaves of plants which are not naturally aquatics, if they be submersed, soon lose them; and although some plants of the higher classes, which grow in the air, have no leaves, yet, these have apertures on the stem, which, in such instances, perform the respiratory function. But the most perfect plants are furnished with leaves which,

from being membranous and from the nature of their attachments, are moveable in the air, and thence have constantly a fresh atmosphere of that fluid applied to their breathing apertures; this mobility of the leaf supplying, in some degree, the motion of the thorax and the diaphragm in the more perfect animals. The plants which have very thick and immoveable leaves, on the contrary, or which are devoid of leaves, as they resemble the cold-blooded and slow-moving animals in their tenacity of life, like them, also, require a smaller supply of air, and consequently, as we have already seen, are less amply supplied with breathing apertures. I have not been able to ascertain whether the apertures themselves have the power of opening and shutting; but from the appearance of the orifices of these organs, as they are seen on the leaf of Indian Corn, when very highly magnified (see Plate 10, fig. 15), it is not improbable that some degree of dilatation and contraction takes place, although we cannot determine the fact. In structure these organs seem well adapted for the purposes of vegetable respiration, when we consider that the changes effected by this function in the sap of vegetables in the leaf are not required to be so quickly produced as those in the blood of animals; even of insects of the lowest description. The air is admitted through the funnel-shaped pore, which perforates the cutis, into a vesicle si-

tuated under it; and which probably communicates with the cuticular cells, as these are in general found filled with air. The aqueous contents of the cells that form the parenchyma of the leaf, are thus brought into immediate contact with the atmosphere. It is not easy to assign a reason why these apertures are found on the under disk only of the leaves of trees, while they appear on both disks of herbaceous leaves; there being lymphatics on both disks of the former as well as of the latter description of leaves. If any connexion could be traced between the returning vessels and the apertures, the difficulty would be diminished, the situation of these vessels being on the lower disk of the leaves of trees.

With regard to the origin of these apertures, M. De Saussure's and M. Kieser's observations would lead us to believe, that they are merely the terminations of numerous vascular processes from the larger fasciculi, which, gradually penetrating the cuticle, are thus enabled to discharge their fluids. This opinion, however, is altogether hypothetical. They are so far essential that they are found on every leaf in contact with the atmosphere; their structural characters, position, and situation, are the same on the leaves of every plant of the same species; and their existence seems to be influenced by no conditional circumstance except the presence of air; for I have al-

ready demonstrated the incorrectness of the assertion, that etiolated leaves are devoid of apertures, or at least the remark is not universally applicable. With regard to the fact, that they are not found on submersed leaves, even of land plants which are made to grow in the water, I may merely observe, that the leaves produced on such plants differ from those which are natural to them, not in the absence of apertures only, but in form, structure, and functions.

The knowledge of the structure of leaves enables us to form a correct idea of the importance of these organs in the economy of the plants. We find the vessels which convey the *sap* from the roots terminating in the leaf, and spreading out their contents through its cells, to undergo certain chemical changes which are essentially influenced by the action of the air and light: we find, also, a new system of vessels commencing here, which take up again the sap thus converted into *proper juice* and conduct it downwards, depositing in their course the various secretions formed from it, either in the stem or in the roots, as the nature of the plant requires; and, in aid of these operations, a cuticular system admirably adapted by its transparency to transmit the rays of light into the foliar cells, and by its organic apertures to admit the air, and at the same time favour the exhalation of the superabundant water, which the ascending

sap necessarily contains. But, besides fitting the sap for yielding the secretions found in the bark, wood, and roots of plants, the leaf itself is a secerning organ, and contains in its cells and follicles many secretions useful, undoubtedly, to the plant itself; but, independent of that, of the first importance in medicine and the arts; and in supplying food for the support of animal life. Thus the leaves of Henbane, Hyosciamus *niger;* Deadly Nightshade, Atropa *Belladonna;* Wolfsbane, Aconitum *napellus* and *neomontanum;* Hemlock, Conium *maculatum;* Fox-glove, Digitalis *purpurea;* the whole genus Tobacco, *Nicotiana;* Wild and Garden Lettuce, Lactuca *virosa* and *sativa;* the genus Thorn Apple, *Datura;* Yellow-flowered Rhododendron, R. *Chrysanthum;* the Poison Oak, Rhus *Toxicodendron,* and many other plants, contain alkaline principles, which produce very powerful sedative and narcotic effects on the animal economy; and the Prussic acid, a still more direct sedative, is present as a secretion in the leaves of the Laurel Cherry, Prunus *Lauro-Cerasus.* Bitter and tonic principles are found in the leaves of the genus Wormwood, *Artemisia;* Centaury, Chironia *Centaurium;* Horehound, Marrubium *vulgare;* Marsh Trefoil, Menyanthus *trifoliata;* Garden Angelica, A. *Archangelica;* Hyssop, Hyssopus *officinalis,* &c.: astringent in those of the Oak genus, *Quercus;* Bears Whortle

Berry, Arbutus *uvæ Ursi;* almost the whole of the genus Sumach, *Rhus;* the Tea, *Thea;* and many other genera: and emetic in Asarabacca, Asarum *Europæum,* &c. The purgative properties of the leaves of Senna, Cassia *senna,* and of Hedge Hyssop, Gratiola *officinalis;* and the diaphoretic of Sage, Salvia *officinalis,* are well known. The secretions of some leaves are so acrid as to inflame and blister the skin when applied to it; as those of many of the species of the genus Ranunculus*; and of Savine, Juniperus *Sabina:* on the other hand, some leaves, as those of Marsh Mallow, Althea *officinalis,* and of Common Mallow, Malva *sylvestris,* afford bland mucilages; others, as those of Sorrel, Rumex *acetosa,* and of Wood-Sorrel, Oxalis *acetosella,* contain cooling acids: and some again, as those of the Mints, *Menthæ;* Balm, Melissa *officinalis;* Rue, Ruta *graveolens;* the Cajuputi tree, Melaleuca *Leucadendron,* &c. secrete essential oils, which rouse and stimulate the animal system when taken into the stomach, or even when applied to the skin. As food, men employ a great variety of leaves, which yield a bland fecula and saccharine

* The leaves of R. *flammula* are used for raising a blister in the Hebrides. They are chopped and rubbed between hot stones immediately before being applied; and generally raise a blister in an hour and a half. The leaves of R. *sceleratus* have the same effect; but often occasion an irritable sore, which cannot readily be healed.

matter, or in which the acrid secretions can be easily destroyed by cooking; and the number of those which might be used for this purpose, but are still neglected, is very considerable*.

No distinct secerning organs have yet been discovered in leaves, except as relates to some saccharine and resinous exudations and to the essential oils; and the organs producing these have been termed *glands*. The exudations give various characters to the surfaces of leaves; but the oils are preserved in distinct follicles; which, in many instances, open by excretory pores, that are readily distinguished from the common foliar apertures; and through these they are exhaled, producing the odours for which many leaves are distinguished. I should now endeavour to demonstrate the forms and structure of these glandular organs; but as they are found sometimes on the stem as well as on the leaf, I shall not confine myself to the examination of them as connected with the leaf only; but as part of the general vegetable *appendages*.

The term *appendage* is applied to certain or-

* The leaves of the common Dock, Rumex *patientia*, were eaten by the ancients under the name of Lapathum; and are still eaten in some places of Germany under the name of English Spinage. The leaves of R. *scutatus* and of many species of the genus *Atriplex*, were also formerly used as pot-herbs, and, indeed, afford very palatable and nutritious food.

gans which are occasionally, but not invariably, found connected with the universal vegetable organs. They are never all present on the same species of plant; but which of them soever is found on any individual is general to the species, and invariably present. All of them are important to the plants on which they are found; and a knowledge of them, besides throwing great light on vegetable physiology, is of utility to the practical Botanist, in affording characters for specific distinctions. The *caulinar* and *foliar appendages,* or those connected with the stem, branches, and leaves, to which we have now to direct our attention, may be classed under the six following heads: *Glands, Pubescence, Spines, Prickles, Props, Foliaceous appendages,* and *anomalies* *.

1. GLANDS, *Glandulæ.* Linnæus has defined the vegetable gland to be "a little tumour excreting "an humour †;" but this definition comprehends those glands only which are external and elevated above the cutis; and, as we find many minute organs of a structure distinct from the common texture of the part on which they are situated, and se-

* I have adopted this term from Mr. Keith, because I can suggest no better for the classification of the objects intended to be described under it.

† "*Glandula* est papilla humorem excernens." *Phil. Bot.* § 84.

parating a peculiar fluid, embedded in the cellular substance, or half sunk in the cutis, and, if elevated above its surface, displaying great diversities of form, its exceptionable character is evident. In rejecting, however, this definition, the difficulty of forming an appropriate one must be acknowledged. A definition formed altogether on the existence of the secretory function, would occasion us erroneously to regard as glandular any part where the presence of a fluid, distinct from the common juices of the plant, might lead us to suspect the operation of that function, although the part should display no organic peculiarity sufficient to authorize the application of the term gland to it. On the other hand, a definition founded on structure alone, or on figure or position, would lead us as far astray. Perhaps we shall arrive nearer the truth if we take into consideration both structure and function, and say that *a vegetable gland is a minute organ, differing in structure from the common texture of the part where it is situated, and separating some peculiar matter from the ordinary vegetable fluids.*

Guided by this definition, we find glands on the stem and leaves, situated both under the cutis and on its surface. In describing these organs some arrangement is necessary; and in looking into books to know what has been done in this way, we find that the arrangement proposed by Guet-

tard, a French Phytologist, who first attempted the subject, has been adopted by almost every succeeding writer. He describes seven species of vegetable glands: the *miliary*, the *vesicular*, the *scaly*, the *globular*, the *lenticular*, the *utricular*, and the *cup-shaped;* but as the cuticular apertures, which he mistook for glands, constitute his first species; and the thin scales which cover the fructification of the Ferns his third, there is sufficient reason for rejecting this arrangement. In attempting another, we must first take into consideration the situation of these minute organs as far as relates to their being under the cutis, or exterior to it; and, consequently, I propose to divide them into two classes, *internal* and *external*, and to subdivide these into genera and species.

A. The INTERNAL caulinar and foliar glands are probably of various kinds, but one only, the follicular, has yet been detected.

1. The follicular gland, *glandula follicularis*, is in the form of a small sac or follicle. It is generally found in the substance of leaves, and is furnished with an excretory duct which opens upon the under disk of the leaf. It is readily discovered by its transparency, which gives the leaf a punctured appearance when it is held up between the eye and the light; as exemplified in the leaves of Perforated Saint John's Wort, Hypericum *perforatum;* All Spice, Myrtus *Pimenta;* the genus

*Citrus*, &c. A beautiful variety of this gland is observed on the leaf of Coffea *Arabica*, situated in the angles formed by the parting of the larger costæ from the midrib: its follicle, which occupies a space rather greater than the thickness of the leaf, forms a small elevation on the upper disk, and opens on the lower by a large excretory pore, guarded by stiff hairs inclining over it.

The real glandular part of the follicular gland is cellular, and forms the parietes of the follicle, which is the receptacle only of the secretion; and this, in general, is an essential oil. As the odours of leaves depend chiefly on the exhalation of their essential oil, they are often regulated by circumstances affecting the excretory ducts of these follicles. Thus the duct being closed by the pressure of the cells turgid with sap, in the fresh stem and leaf of Sweet-scented Vernal Grass, Anthoxanthum *odoratum*, no odour is perceived; but it opens, when these cells shrink, as the grass dries, and, then, the agreeable perfume which is peculiar to new hay is exhaled. The odour is permanent in some plants, as Mint, Sage, &c. but very evanescent in others, as, for example, in the leaves of Gaultheria *odorata*, which yield a very agreeable odour when fresh, but become scentless a few hours after their separation from the tree.

B. The EXTERNAL caulinar and foliar glands

are more easily detected than the internal, and appear to be more numerous. They may be arranged under two genera, the *sessile* and the *pediculated;* and each of these subdivided into species.

*a.* The *sessile* gland lies on the surface of the stem, or of the leaf, or is slightly depressed in the cutis. It comprehends three species:—the *simple papillary,* the *compound papillary,* and the *scaly* glands.

1. The simple papillary gland, glandula *papillaris simplex,* is usually situated on the lower disk of leaves; and, in many instances, it appears, to the unassisted eye, a mere pore, exuding a drop of viscous or oily fluid; but is, in fact, a small tubercular elevation. Thus on the back of the leaf of Crescent-leaved Passion-flower, Passiflora *lunata,* the dark spots seen by the naked eye on each side of the midrib, are found to be slightly elevated, circular, papillary glands, with an apparent pore in the centre (Plate 9, fig. 27. *a.*) when viewed with a good glass; but when the gland is placed under the microscope, the pore is discovered to be a depression only, covered with a very thin transparent epidermis, which extends over the whole surface of the gland. In general, however, the papillary glands are more conspicuous; and appear, even to the unassisted eye, small elevated bodies, with a broad base, placed, in some instances, as it were, in a socket. Their structure is cellular; but the

cells are smaller, more regular than those of the substance of the leaf, and arranged in circles. I have not been able to detect any vessels passing into these glands, nor to discover their excretory pores; except in the sting of the nettle, which is the excretory duct of a papillary gland. A variety of this gland, generally described as a distinct species, under the name lenticular, *glandula lenticularis*, is found on the surface of the stems of Stripe-flowered Psoralea, P. *glandulosa*, and of many other dicotyledons. It is a small follicle, which generally contains an oily or a resinous fluid; and differs from the internal follicular gland only in its situation on the surface.

2. The compound papillary gland, *glandula papillarum composita*, is best exemplified as it is found on the leaf of the Stone Pine, Pinus *pinea*. If we examine the surface of this leaf, with a good magnifying glass, we find that it is streaked with whitish lines, on which are seen small black spots arranged in a regular series (Plate 9, fig. 28. A.). Under the microscope each of these spots is discovered to be the excretory pore of a compound gland, composed of six distinct glandules, forming a ring or collar (fig. 28. B. *a.*) around the pore (*b.*), which generally appears obstructed by minute, dark-coloured, terebinthinous particles; and is seen to be really a pore, only when the cutis is very carefully raised. The glandules

resemble the papillary glands in some degree, each being a slight elevation with a depression in the centre; and it is probable that these are the secreting organs, and, severally, communicating with the excretory pore, pour the fluid they secrete into it; whence it is exuded: and acquires its dark colour by exposure to the atmosphere.

3. The scaly gland, *glandula squamosa* *, resembles a minute scale attached to the surfaces of the leaves on which it is found, as, for instance, on that of Rhododendron *punctatum*. The under surface of this leaf is covered with glands of this species, which appear, when viewed with a good glass, like small brilliant detachable scales, white and shining round the edge and dark in the centre (Plate 9, fig. 29. A. *a*.). When one of these scales is placed under the microscope, the white border is found to be beautifully fluted (fig. 29. B. *b*. *c*.), and lying flat upon, but not attached to the surface of the leaf; and to be the loose margin of the scale covering the gland, which appears to be a slightly elevated papilla, discharging its secretion by several excretory pores which open upon the surface. The real shape of the gland, however, is that of an inverted cone, of which the scale is the base.

* I am surprised that the error of Guettard, who gave this name to the thin scale which covers the fructification of Ferns, has been copied by Mr. Keith in his System of Physiological Botany. See vol. i. p. 69.

It is seated in a depression of the cutis, and communicates with the interior of the leaf by means of a duct, which passing through the apex to the base of the cone penetrates the cutis. The texture of this gland is cellular; and its secretion is an essential oil. The leaves of the Sea-side Balsam, Croton *Eluteria,* furnish examples, also, of the scaly gland *.

*b.* The pediculated gland is elevated from the surfaces on which it is found, by an interposed pedicle or stalk. It comprehends four species, the *cup-shaped,* the *knob-like,* the *stipitate,* and the *branched* glands.

1. The cup-shaped gland, *glandula cyathiformis,* as its name imports, resembles a shallow cup or saucer, supported on a thick, short, footstalk (Plate 9, fig. 30). It is found on the petioles of some leaves, as, for instance, those of the Nectarine, Amygdalus *Persica,* and the Passion-flower; and in the serratures of others, as those of the Bay-leaved Willow, Salix *pentandra,* &c. The secretion is generally of a resinous character, and exudes from the hollow part of the gland, which is devoid of epidermis. This species of gland, like the majority of the external glands, is cellular, and we can distinctly trace into it a cord of both

* Sprengel has figured these in his *Elements of the Philosophy of Plants* (P. vi. fig. 8); but regards them merely as scales.

spiral and proper vessels, which, apparently, terminates in the substance of the gland.

2. The knob-shaped gland, *glandula claviformis,* resembles a knob or a small nail, which, in the language of the artisan, has not been driven home. The head, which is the glandular part, is slightly convex on the upper surface; and displays a rough striated border, encircling a round flat spot devoid of epidermis (Plate 9, fig. 31), from which the secreted fluid is discharged. The internal structure of this gland closely resembles that of the cup-shaped gland. It is generally found either on the stem or the petiole of the leaf, or on both in the same plant, as for instance in the Castor-oil plant, Ricinus *communis.*

3. The stipitate gland, *glandula stipitata,* is so named from being supported on a long slender stalk (Plate 9, fig. 15), and is, in fact, a stalked variety of the cyathiform gland. It is the smallest of the external glands, and is situated either on the margin of leaves, as in Croton *penicillatum;* or on the disk, as in Sun-dew, Drosera *rotundifolia.*

4. The branched pediculated gland, *glandula pediculata ramosa,* is a small hemispherical gland supported on a branched stalk (Plate 9, fig. 32). The appearance of moss on the stem of the Moss Rose is produced by glands of this description. The individual glands are cellular, devoid of epidermis, and each is furnished with vessels, which are branches of a fasciculus, which enters the

gland-bearing stalk at its base. These glands generally secrete a viscous resinous matter, which is also sometimes odorous.

The minuteness of the vegetable glands prevents me from attempting to offer you any anatomical demonstration of their structure. They have, indeed, been arranged into *cellular* and *vascular* glands by writers who have endeavoured to trace their structure, and who have stated some of them to be entirely cellular, and others chiefly vascular; but as we can scarcely suppose that any part, completely devoid of vessels, possesses the function of secretion, we must receive these statements with caution. With regard to the use of glands to the plant, at least as far as relates to the conservative organs, we know nothing. They, probably, do not play so important a part in the vegetable as in the animal economy; but we can hazard nothing more than conjecture on the subject.

ii. Pubescence, *Pubescentia*. Under this term are included all the kinds of down, hairs, and bristle-like bodies, found on the surfaces of the conservative organs. They differ very considerably in form and texture, and on these differences I shall attempt such an arrangement of them as may facilitate your knowledge of the subject.

All vegetable pubescence consists of small, slender bodies, which are either soft and yielding to the slightest impression, or rigid and compa-

ratively unyielding; the former are, properly speaking, hairs *(pili)*, the latter bristles *(setæ)*; and, therefore, under these two heads every kind of pubescence may be arranged.

A. Hairs, *Pili*, are fine, slender, cylindrical, flexible bodies found on the surfaces of the herbaceous parts of plants. Some of them are the excretory ducts of glands, a fact which was first detected by Guettard; and on which Linnæus too hastily formed his definition of the hair, which he describes generally to be "a bristle-like ex-"cretory duct of the plant *;" but many of them are not excretory ducts, and it is not easy to conceive any satisfactory opinion of their use to the plant. In some instances indeed they serve one of the purposes which Linnæus ascribes to them; that of defending the plant from external injuries †, as we find downy and hairy leaves are not so frequently attacked by insects as smooth ones; but they can be very imperfect safeguards against heat, cold, or wind ‡.

When placed under the microscope, vegetable hairs appear to be membranous tubes, articulated in the majority of instances, often punctured, and

* "Pilus est ductus excretorius plantæ setaceus." *Phil. Bot.* § 84.

† "Pubescentia est armatura plantæ, qua ab externis in-"juriis defenditur." *Phil. Bot.* § 163. viii.

‡ "Lana servat plantas ab œstu nimio. Tomentum servat "plantas a ventis." *Phil. Bot. l. c.*

in some plants, as Borago *laxiflora,* covered with warts. They are either *simple* or undivided, or *compound* or branched.

1. *Simple* hairs *(Pili simplices).* The commonest form of the simple hair is that of a jointed thread generally too flexible to support itself; therefore it is more commonly found variously bent and waved (Plate 9, fig. 10. *a. b.*)*. According to its degree of fineness, its quantity and the mode of its application to the surfaces of stems and leaves, it constitutes the characteristics of surfaces: thus the surface is termed hairy *(pilosus)* when the hairs are few and scattered, but conspicuous, as in Mouse-ear Hawkweed, Hieracium *Pilosella;* woolly *(lanatus),* when they are complicated, but, nevertheless, the single hairs are distinguishable, as in Mullein, *Verbascum;* shaggy *(tomentosus),* when they are so thickly matted that the individual hairs cannot be distinguished; and when the position of the hair is nearly parallel to the disk, being at the same time straight or very slightly curved (Plate 9, fig. 10. *c.*), and thick although unmatted, it constitutes the *silky* surface, as in the leaves of Wild Tansey, Potentilla *anserina;* Silvery Ladies' mantle, Alchemilla *alpina,* &c. In some instances the simple hair is firm enough to support itself erect;

* In all the figures of hairs and bristles in Plate 9, the size of the appendage, when viewed with a common lens, is placed beside its highly magnified representation.

in which case it is usually awl-shaped, and the articulations are shorter towards the base, as in White Bryony, Bryonia *alba* (Plate 9, fig. 11): it does not always, however, terminate in a point, but sometimes in a small knob, as on the newly evolved, succulent shoots of ligneous plants, on *Belladonna,* &c. (*ib.* fig. 12). In some instances, also, as on the under disk of the leaves of Comfrey, Symphytum *officinale,* and Agrimony, Agrimonia *Eupatoria,* the simple hair is hooked towards its apex (*ib.* fig. 13, 14); which occasions the velvety feeling when the finger is passed over the surface of these leaves, the convex part of the curve of the hair being that only which comes in contact with the finger. Another variety of the simple hair, necessary to be noticed, is that which has given rise to the term *glanduloso-ciliata.* It is a slender hollow thread supporting a small, cup-shaped, glandular body; and is rather to be regarded as a stipitate gland, under which name I have already noticed it, than as a hair.

2. The *compound* hair *(Pilus compositus)* is either feathery *(plumosus),* which is a simple hair with other hairs attached to it laterally, as in wave-leaved Hawkweed, Hieracium *undulatum;* or it is branched *(ramosus),* that is, lateral hairs are given off from common stalks, as on the petiole of the Gooseberry leaf; or it consists of an erect,

rather firm stem, from the summit of which smaller hairs diverge in every direction (Plate 9, fig. 16), as in Marrubium *peregrinum*, Melhania Erythroxylon, &c.; or it is starlike *(stellatus)*, being composed of a number of simple diverging awl-shaped hairs, springing from a common centre, which is a small knob sunk in the cutis (*ib.* fig. 17), as on the leaves of Marsh Mallow, Althæa *officinalis.* Some authors have applied the term *ramenta* to small, flat, or strap-like hairs, which are found on the leaves of some of the genus Begoniæ; but I agree with Sir E. J. Smith *, that they "do not merit "to be particularly distinguished," and form merely a variety of the simple hair.

B. Bristles, *setæ.* These are, also, hollow tubes, which are often of a different texture from that of the cutis of the leaf; being rigid, sharp-pointed, and either wounding the finger when it is pressed upon them, or giving a very harsh, scabrous, or prickly character to the surface of the stem, or of the leaves when the finger is rubbed over them. They are often arranged with prickles *(aculei)*, in elementary works; but they have more affinity to hairs; and, therefore, I have placed them under the head of pubescence. They are *simple* and *compound.*

*a. Simple* bristles *(setæ simplices)* are of two kinds, the *awl-shaped* and the *spindle-shaped.*

* *Smith's Introduction,* p. 227.

1. The awl-shaped bristle *(setæ subulata)* is the most common of the simple bristles: it is slightly curved, and gradually tapering from the base to the apex (Plate 9, fig. 18), which is rigid and very sharp. These bristles, when they all incline in the same direction, produce the scabrous character of some leaves, which is perceived when the hand is passed lightly over their surface, from the apex towards the base; as exemplified in those of Symphytum *orientale*, and many other plants. A variety of the subulate bristle, found on the stem and branches of the Sensitive Plant, Mimosa *sensitiva*, is barbed on its sides (Plate 9, fig. 19); and another variety, as exemplified on the leaves of Borage, Borago *officinalis*, is seated on a vesicular tubercle (*ib.* fig. 20), containing a fluid, which is ejected through the bristle when it is compressed so as to wound the finger; and which, being left in the wound, excites a slight degree of inflammation in the part. But the sting of the Nettle is the best example of this form of bristle, when it is an excretory duct of a gland; and it has, not inaptly, been compared to the fang of a serpent. Its structure has been known since the time of Hook, who first described it *. It consists of two distinct parts: one, to employ Hook's language, "like a bodkin, very hard and stiff,

* *Micographia*, p. 142.

"exceedingly transparent, and hollow from top "to bottom; the other, a little bag more pliable "than the bodkin, and within it a cellular struc- "ture, which contains a thin transparent liquid." In figure 21, Plate 9, *a.* represents the hollow bristle, with a drop of fluid hanging upon its point; *b.* the cellular bag or sponge which contains the poison, and in which, also, it is probably secreted. When the bristle penetrates the skin of the finger, or any other part of the body, it is pressed down upon the sponge, from which a quantity of the liquid is thus squeezed, and rising in the tube, is ejected and deposited beneath the skin, causing the inflammation and painful irritation which succeed.

2. The *spindle-shaped* bristle *(seta fusiformis)* is, as its name implies, thickest in the centre and acuminated at each end. It lies parallel to the surface of the leaf, to which it is fixed by a very short footstalk (Plate 9, fig. 22); is hollow, and contains a coloured liquid, which apparently enters it through the footstalk: but I have not been able to discover any opening in the bristle, through which it could be ejected, as in the sting of the Nettle. This form of bristle is peculiar to the genus *Malpighia,* at least I have never met with it on any other plants.

*b. Compound* bristles *(setæ compositæ)* are

almost always solid. The term comprehends two species of bristles: the *forked* and the *fasciculated.*

1. *Forked* bristles *(setæ furcatæ)* are, in some instances, merely rigid, hairlike bodies terminating in two or three diverging points (Plate 9, fig. 23, 24), as in Thrincia *hispida;* but in other cases, as, for instance, on the stems and leaves of the Hop plant, Humulus *lupulus,* the stalk of the bristle, which is supported on a firm cellular tubercle, is very short, and its forking extremities resemble two flattish, awl-shaped bristles (Plate 9, fig. 25) pointing in opposite directions.

2. *Fasciculated* bristles *(setæ fasciculatæ)* consist of a number of simple straight bristles diverging from a papillary knob, as in Cactus *flagelliformis* (Plate 9, fig. 26).

There is still another species of pubescence that cannot properly be arranged with any of those which have been described; it is found on a species of Houseleek, Sempervivum *arachnoïdeum,* extending like a very fine thread, stretching from the tip of one leaf to that of another, and resembling so exactly a spider's web, that the plant has been named *arachnoïdeum.*

The pubescence of plants is liable to be affected by climate, soil, culture, and other circumstances: thus, to mention a few only of these changes, Sweet-scented Woodruff, Asperula *odorata,* is villous, or covered with shaggy hairs, when it grows in the shade, and scabrous when in ex-

posed places: the Turk's-cap Lily, Lilium *Martagon*, is found covered with rough hairs, or hirsute, in the woods, and yet is smooth when cultivated in gardens; and some of the Mint tribe, as for instance Mentha *hirsuta*, naturally hairy, are occasionally found smooth; and yet, "if "transplanted soon resume their former habits*." Notwithstanding these changes, and although Linnæus regards distinctions founded on pubescence as ridiculous †, yet systematic Botanists have successfully founded specific distinctions on the direction of the pubescence; for, as it has been justly remarked, although "the *degree* of pubes-"cence varies from culture, and even its *struc-"ture* be changeable," yet "its *direction* is as "little liable to exception as any character that "vegetables present ‡:" and, consequently, in treating of the hairs and bristles on plants, their direction is necessary to be noticed. When the hairs are placed in a line on two sides only of a stem, the pubescence is said to be bifarious *(bifariam pilosus)*; as in Germander, Veronica *Chæmædrys;* its direction is horizontal *(horizontalis)* on the flower-cup in Corn Mint, Mentha *arvensis;* and on the stems of the common Red Poppy, Papaver *Rhœas;* and patent or spreading *(patens)* on the

* *Smith's Introduction*, p. 228.

‡ *Ibid.* p. 229.

† "Pubescentia ludicra est differentia, cum cultura sæpius "deponantur." *Phil. Bot.* § 272.

pedicles of fragrant sharp-leaved Mint, Mentha *acutifolia.* In these and similar instances the direction forms essential distinctions in the specific characters of the plants. Indeed, Sir E. J. Smith, speaking of the direction of the hairs about the calyx and flower-stalk in the Mint tribe, says, "I have found it the only infallible distinction between one Mint and another." Hairs are said to be ascending *(ascendentes)* when they are directed towards the summit of the part on which they are seated; descending *(descendentes)* when towards the base; and appressed *(adpressi)* when they are closely applied lengthways to the part, as on the peduncle of long smooth-headed Poppy, Papaver *dubium,* which is distinguished from the common red Poppy chiefly by this character. A very curious effect of the direction of hairs is perceived in the pitchers or *ascidia* of Sarracenia, and in some tubular flowers. The stiff hairs, in these instances, by pointing inwards and towards the bottom of the cavities in which they are found, perform a service similar to the wires which point inwards at the mouth of a mouse-trap, preventing insects which enter these cavities from escaping out of them.

With regard to the uses of the hairs, some Phytologists have considered them to be transspiring and absorbing organs. I have already demonstrated that the cuticular pores are the trans-

piratory organs of plants; and, independent of other reasons that might be advanced against the opinion that they are absorbents, we have only to notice the fact, that the succulent plants of arid soils, which live almost entirely by cuticular absorption, are often nearly devoid of hairs: besides, they are observed in the interior of plants, as in the vacuities within the stems of aquatics, where their absorbent function, did they possess it, is not required. Whether their presence can modify the action of light, air, and temperature upon plants, has not yet been determined; and we must confess that we are still ignorant of the use of these minute organs in the vegetable economy.

iii. THORNS, — *Spinæ.* These are rigid, sharp-pointed processes firmly connected with the texture of the parts on which they appear*. They are either simple or compound. The simple spine *(spina simplex)* is a slender tapering body terminating in a sharp point, and covered with a bark and cuticle the same as those of the stem or the branch: it is, also, generally *solitary*, as in the common Hawthorn (see cut 1, p. 268) and the Cockspur-thorn, Mespilus *oxycantha*, and *Crus galli*; Box-leaved Staff Tree, Celastrus *buxifolius*, &c. The compound spine *(spina composita)* comprehends several kinds, which are named according-

* Linnæus defines the thorn thus: "*Spina* est mucro plantæ "e ligno plantæ protrusus." *Phil. Bot.* § 84. 3.

ing to the number or division of their parts: thus it is termed forked *(bipartita)* when it is divided into two points, or appears like two simple spines, united near the base; as in two-spined Arduina, Arduina *bispinosa:* three-pronged *(tripartita)*, when there are three points, as in three-thorned Gleditchia, Gleditchia *triacanthes;* and branched *(ramosa)*, when it is divided into many lateral points.

In respect of situation, thorns are *caulinar*, *petiolar*, or *foliar*. They are said to be terminal *(terminales)* when they are situated at the termination of a branch or shoot, as in Buckthorn, Rhamnus *catharticus;* axillary *(axillares)*, when seated in the upper angle formed by the petiole of the leaf and the branch, as in the Lemon tree, Citrus *medica;* superaxillary *(superaxillares)*, when a little above that angle, as in Gleditchia *triacanthes;* and subaxillary *(inferaxillares)*, when in the opposite situation.

The anatomical structure of the thorn is, with a few exceptions, the same as that of the branch on which it remains as a part, after the bark is removed; and in many instances it appears to be merely an abortive shoot, arising, as Malpighi suggested, from defective nutriment; but this cause can be regarded as occasional only, for, were it general, every description of thorn would entirely disappear under culture, which is not the

case. In some instances, however, as in the Pear tree, Pyrus *sativa,* and in some other fruit-trees which have thorns in their wild state, they disappear by culture. The petioles of several pinnate leaves, as those of Astragalus *Tragacantha,* which are persistent, become acuminated, and change into thorns, after the leaflets fall; the peduncles, also, of some flowers, as those of *Pisonia,* undergo a similar transformation: and in the genus *Mimosa* and a few other tribes of plants, we find that the stipules* sometimes become ligneous, and pass into thorns. The structure of the *foliar* thorn, which appears either on the margin of the leaf or on the costæ, does not so closely resemble that of the part on which it is seated. It generally consists of a cord of vessels derived from the nearest fasciculus of the leaf, enclosed in a firm cellular tissue, and covered with a horny cuticle.

iv. PRICKLES, *Aculei,* may be defined rigid sharp-pointed processes that do not adhere firmly, but come off with the bark of the parts on which they are seated (see cut 2 p. 268)†. They are, in general, laterally compressed, and either straight

* As these organs have not yet been described, it is necessary to state here, that they are small foliaceous appendages, generally situated on each side of the base of many petioles.

† "*Aculeus* est mucro plantæ, ejusdem cortici tantum affixus." *Phil. Bot.* § 84. 4.

*(recti)*, that is, free from any curvature, and diminishing gradually from the base to the apex, as on the Scotch Rose, Rosa *spinosissima;* or curved *(curvi)*, as on the Bramble, Rubus *fruticosus.* If the curved prickle have its point directed upwards, it is said to be incurved *(incurvus vel inflexus)*, and if in the opposite direction, recurved *(recurvus vel reflexus)*. It is, also, in some instances spiral *(circinnatus)*, with the apex turned inwards, as in the genus *Hugonia.* Like the thorn, the prickle is *simple* or *compound*, according as it has one or more points; and it is termed *caulinar*, *petiolar*, or *foliar*, from its situation being on the stem, or on the branch, the petiole or the leaf. It is in general solitary; but in some plants prickles are always found in pairs *(geminati);* and on others, as for example the Barberry, Berberis *vulgaris*, several stand together on the same plane, and are said to be palmated *(palmati)*. Prickles consist of condensed cellular matter covered with an epidermis, which becomes dry, hard, and coloured with age. They originate immediately under the cuticle; and when picked off leave no impression deeper than the exterior layer of the bark. Indeed in the majority of instances they appear to be productions of that layer, and consist altogether of a mass of oblong cells, which become more condensed and tubular as they approach the point, and over which the

common cutis of the part on which they are situated is reflected. Willdenow states the prickle to be vascular; but I have not been able to detect any vessels in it, unless we regard the tubular cells as vessels *. They are a more permanent appendage than thorns; not at all liable to disappear by culture; and, consequently, are better fitted for forming specific distinctions.

Linnæus regarded thorns, prickles, and bristles as the armour of plants; and the poetical imagination of Darwin has led him to suppose, that the great Author of all things has impressed on organized bodies "a power of producing armour "to prevent those more violent injuries which "would otherwise destroy them †;" and, consequently, that plants, now unprotected, may obtain bristles and other defensive organs in the progression of time. But although the depredations of animals upon the tender foliage of plants are occasionally checked by these organs, yet, such fanciful notions as those I have just quoted, and indeed most of those which our reasonings upon final causes lead to, are neither philosophical nor accordant with correct observation; and we must

* Willdenow, in his Principles of Botany, § 270, says, "This (the prickle) consists of reticular, more or less ex-"panded, adducent vessels, and a few air vessels, and is co-"vered with the vascular cutis." *Translation.*

† *Phytologia*, Sect. xiv. 3. 2.

confess our ignorance of the utility of this description of armature in the vegetable economy. Man, however, has ingeniously taken advantage of its existence for his peculiar benefit; and many of those spiny and prickly shrubs, which originally opposed his progress in penetrating to the depths of the primeval forests, are now trained as useful and ornamental fences around those portions of the soil which the arm of Cultivation has wrested from the dominion of Nature.

v. PROPS, *Fulcra*. Under this term, Linnæus and several other phytological writers have comprehended a variety of vegetable appendages, which afford no prop or support to the plant *. I confine its application to those organs by which climbing and weak flexible stems attach themselves to one another, to firmer plants, and to other objects in their vicinity, for support. By these means many plants, which would remain prostrate upon the earth, elevate themselves to the summits of the highest trees; and, in tropical countries, where vegetation revels in all the luxuriance of its powers, the *Lianas*, as these plants are termed, hanging down in festoons adorned with blossoms, form the richest garniture of the forests. There are four kinds of vegetable props, the *tendril*, the *claw*, the *hook*, and the *bladder*.

* " *Fulcra* adminicula plantæ sunt, pro commodiore sus-
" tentatione; numerantur hodie vii. *Stipula, Bractea, Spina,*
" *Aculeus, Cirrhus, Glandula, Pilus*." *Phil. Bot.* § 84.

*a.* The tendril, *Cirrhus**, is a long, cylindrical, slender, spiral body issuing from various parts of plants. The tendril is either simple *(simplex)*, consisting of one undivided piece, as in Bryony, Bryonia *dioica*, and square-stalked Passion-flower, Passiflora *quadrangularis* (Plate 4, fig. 8. *a. a.*); or compound *(compositus)*, consisting of a stalk variously branched or divided. When there are two divisions, the compound tendril is termed bifid *(bifidus)*, as in Marsh Lathyrus, L. *palustris*, Smooth Tare, Ervum *tetraspermum*, &c.; trifid *(trifidus)*, when there are three, as in rough-podded Lathyrus, L. *hirsutus*, and in the Garden Pea; and branched *(ramosus* vel *multifidus)*, when the divisions are more numerous, as in Everlasting Pea, Lathyrus *latifolius* (Plate 4. fig. 7); climbing Cobea, C. *scandens*, &c. Tendrils rising from the stem, or the branches, in the axillæ of the leaves, are named axillary *(axillares)*, as exemplified in the Passion-flower (Plate 4, fig. 8); subaxillary *(subaxillares)*, when they originate below the leaf; lateral *(laterales)*, when at one side of it, as in Bryony; and opposite *(oppositifolii)*, when they are directly opposite to the insertion of the leaf, as in the Vine, *Vitis*. They are said to be petiolar *(petiolares)*, when terminating the common petiole of a compound leaf, as in Everlasting Pea (Plate 4, fig. 7);

* "*Cirrhus* est vinculum filiforme spirale, quo planta alio "corpori alligatur." *Phil. Bot.* § 84. 5.

and foliar *(foliares)*, when they are a continuation of the midrib of a simple leaf, as that of superb Gloriosa, G. *superba*. The petiolar tendril is sometimes distinguished by the number of leaflets which grow under it; thence we find in systematic authors the terms Cirrhi diphylli, tetraphylli, and polyphylli. The flower-stalks even of some plants, as those of smooth-leaved Heartseed, Cardiospermum *Halicacabum*, bear tendrils.

Tendrils closely resemble petioles in their structure; but not so intimately as to lead us to adopt the opinion of Willdenow, that they are merely petioles, which not having exhausted their sap in forming the leafy expansion, become too feeble to keep their straight direction, and have thence acquired their twisted shape*. If we examine a transverse slice of a tendril of Bryony, under the microscope, and compare it with a slice of the petiole which rises at its side, we shall find that although they agree in some particulars, yet, they differ in others. The cortex of both closely resembles that of the stem (see p. 415); and the internal structure in both, also, consists of fasciculi of spiral and proper vessels embedded in a cellular parenchyma. But the number of these fascicles in the petiole is always nine, and in the tendril four or five only: in the former, also, the

* *Principles of Botany*, § 271.

fascicles are of different sizes, and arranged in a regular series according to their sizes, the largest being towards the convex side of the petiole, and the two smallest, which are more distant from one another than the others, at each angle of the concave side; whereas all are of the same size and equidistant in the tendril. The structure of the fascicles themselves also differs, for, in the tendril, we find three spiral vessels only in each fascicle, arranged in one line extending inwards; while in the petiole each fascicle contains from five to nine of these vessels arranged in two or three lines. From these remarks, although we find that the structure of the tendril closely resembles that of the stem and the petiole, yet, it is evident that this organ cannot be regarded as an abortive leaf. The resemblance of the tendril to the stem is even still closer, as far as regards the cutis, for in both we find pneumatic pores, in that portion of it which covers the green streaks; a fact which suggests the idea that these streaks perform, in both, the functions of the foliar expansion. But the most satisfactory proof of the affinity of all these parts is the fact, that a young shoot, which Mr. Knight grafted upon the tendrils of the Vine, succeeded nearly as well as if the operation had been performed on the stem or the branch. This similarity of structure occasionally produces the transmutation of one part into another: I noticed

to you that of petioles and other organs into spines; and I have now to state that a similar change into tendrils is occasionally observed: as exemplified in the stipules in *Smilax*.

The tendril is at first tender, green, and put forth in a straight direction; but it gradually becomes firmer in its texture, occasionally acquires colour, and always assumes the spiral character. When all the gyrations are regular in the same direction, the tendril is said to be convolute *(convolutus)*; and revolute *(revolutus)*, when it winds itself irregularly, sometimes on one side, sometimes on the other. Phytologists have endeavoured to explain the cause of the spirality of tendrils: their opinions, which are by no means conclusive, shall be noticed when we treat of the movements of plants.

*b.* The claw *(clavicula)* is a small thread-like body which is protruded from the stems of some plants; and adheres so firmly to the surfaces of other bodies, as to enable the plants producing it to elevate themselves from the ground. By means of this description of prop, the Ivy and the Cissus climb not only to the summits of the highest trees, but up the face of the smoothest perpendicular rocks, and to the battlements of the loftiest towers; thus rendering picturesque the monotony of the naked cliff, and, by the richness of their living tracery, adding a new interest to the mouldering pile of antiquity.

There are two varieties of vegetable claws, the *cirrhal* and the *radicular*.

1. The cirrhal claw *(clavicula cirriformis)* resembles the branched tendril, except that each of the branches is terminated by a small fleshy knob; which spreading out in the shape of an oval disk, adheres strongly to a wall or any flat surface with which it comes in contact. In the Virginian creeper, Cissus *hederacea*, the claw, which is of this description, is opposite to the leaf, like the tendril of the Vine, and is spiral in its branches, so that it performs a double office, acting sometimes as a tendril by twining round slender cylindrical bodies, but more frequently as a claw. The internal or anatomical structure of this species of claw, as far as regards its stalk and branches, is exactly the same as that of the tendril, and, like it, originates from the alburnum of the stem: the claw itself consists chiefly of cellular matter, which, being a continuation of the pith of the other parts of the organ, is here checked in its extension and swells out laterally. The under part of the claw is covered with scarcely any cutis.

Three theories exist with regard to the mode by which this organ adheres to smooth surfaces: some writers adopting the opinion of Malpighi, that it is produced by a viscous fluid, which is furnished by small papillæ on the under surface of

the disk or flattened knob: others contending that the adhesion is produced by the disk acting like a piece of thick moistened leather at the end of a cord, such as boys employ for lifting stones, which adheres by the external air pressing it closely to the surface on which it is applied: and a third set imagining that it operates by exhausting the air in the same manner as is done by the foot of the fly, and of one species of lizard, which can run up smooth perpendicular walls, and along the ceilings of rooms*. I am disposed to set aside all these opinions, and to regard the attachment as the effect of a real radication; having found that the inferior surface or sole of the knob, which terminates each branch of the claw, is studded with minute stellated fibrils; which entering into the almost invisible pores of stone, bricks, &c. swell, and maintain the claw firmly attached. I am confirmed in this opinion, by the fact, that these claws will not adhere to glass, to Parker's cement, and other very close grained bodies; and that they adhere strongly to stones and other bodies long after the death of the plant.

Like tendrils these claws turn always from the light; and, from the experiments of Mr. Knight,

* For a description of the apparatus necessary for producing this effect in the foot of the lizard, see a paper by Sir Everard Home, *Phil. Trans.*

this property is so strong, that a piece of dark-coloured paper placed at the distance of a few inches from them, and changed to different sides of the plant, has the power of altering their direction. The cause of these movements shall be afterwards investigated.

2. The radicular claw *(clavicula radiciformis)* is a small cylindrical body, resembling a radicle, which is protruded from the stem; as exemplified in the Ivy and the Ash-leaved Trumpet-flower, Bignonia *radicans.* The claws of the Ivy are protruded in lines, generally on the side of the stem which is next to the wall on which the plant is supported (fig. 1. p. 250). This is probably owing to the greater moisture and shade on that side being favourable to their formation, as in the case of the real roots *, which appear on a stem by surrounding a portion of it with a ball of moist earth; or of those which protrude spontaneously under peculiar circumstances, as in the case of the Laurel, mentioned in page 197: nor is this opinion rendered more problematical by the fact, that the radicular claws are put forth on every side of the older stems of the Ivy, giving them a bristled aspect; for, as in the case of branches and roots, the rudiments of these claws may exist in the stem, although they are not protruded, until cir-

* I have already noticed (p. 280) the fact, that these claws become perfect roots under certain circumstances.

cumstances favouring their development occur: and the stem having ceased to throw out claws on the side next the wall where they originally appeared, a smaller degree of shade and moisture is now sufficient for the development of those which remain unprotruded. In plants of Bignonia *radicans*, which are not trained upon a wall, but supported by sticks in pots in the greenhouse, the claws are put forth in clusters at four opposite points around the stem near the base of each pair of leaves; for here, circumstances being equal on all sides, the power of the stem to protrude claspers is not diminished in one part by being increased on another, and, consequently, the natural effort takes place on all sides, in the same degree.

In structure, the radicular claw closely resembles both the petiole and the radicle. In the Ivy it consists of a cortex inclosing a cellular mass in which the vessels are embedded, and arranged in five distinct fasciculi, which evidently proceed from those of the ligneous, or rather alburnous part of the stem, although Mr. Knight has remarked *(Phil. Trans.* 1812) that the claw of the Ivy "appears to be a cortical production only." The vascular fasciculi are given off nearly at right angles with those of the stem; and are placed at equal distances from one another, in a circle nearer to the centre than to the cortex of

the organ. In Bignonia the vessels appear more condensed, forming one large central fascicle. The epidermis in both is studded with minute fibrils like the radicle; and these are the real adhering organs when the claw is applied to any solid body; for the adhesion is not confined, as in Cissus, to a knob at the point of the organ, but extends over as much of its surface as is in contact with the body to which it adheres.

Some writers have classed with this description of prop the small tubercles, or absorbing warts *(haustoria)*, by which a few parasitic plants, for instance the Dodder, *Cuscuta*, fix themselves on other plants. But these warts are of a mixed character, performing, under all circumstances, at the same time, the functions both of an attaching prop and of a nutrient absorbing organ.

*e.* The bladder *(ampulla*)*. This is a small membranaceous bag attached to the roots and the immersed leaves of some aquatic plants, rendering them buoyant: on which account I have placed it among the props. In shape, the bladder is generally globular; but in common Hooded Milfoil, Utricularia *vulgaris*, it is pear-shaped. It contains a watery fluid and a small bubble of air, which enables it to give buoyancy to the parts to which it is attached; and which must be either

* Linnæus terms it a follicle. "Folliculi sunt vasa aëre "distenta." *Phil. Bot.* § 163. ix. 2.

separated from the water, and absorbed through the substance of the sac, or is a secretion of the plant. All the species of Utricularia, which are not uncommon in our ponds and ditches, have these bladders attached to the roots; but in Aldrovanda *vesiculosa*, an inhabitant of the Italian marshes, they are present as foliar appendages.

*d.* The hook *(hamus)* is generally described among the bristles, and in point of structure, in the majority of instances, it certainly belongs to these bodies; but I prefer placing it here, as it is in every sense of the word a real fulcrum. It is well illustrated in Cleavers, Galium *Aparine*, the angles of the stalk and the margin and midrib of the leaves of which are furnished with hooks, which enable the plant to climb to the tops of the hedges near which it is generally found. The most beautiful specimen, however, of the vegetable hook is found on the pitcher of Nepenthes (see p. 672), in which it serves the purpose of supporting that curious appendage, when it is overloaded with fluid.

vi. *Foliaceous appendages.* These, as their name implies, resemble leaves in several particulars; and this similitude extends even to their anatomical structure. There are three kinds of foliaceous appendages; the *stipule*, the *bracte or floral leaf*, and the *pitcher*.

*a.* The stipule *(stipula)* is a foliaceous organ,

which in some instances accompanies the proper leaf, yet is distinct from it: and, in others, is attached to the petiole, appearing as a part of the leaf itself*. It is not a universal and not always a permanent organ. In some instances it is fugacious *(fugax, caduca)*, accompanying the leaves in the bud only, and falling at the moment of their evolution, or before they are fully expanded; as is the case in the Lime tree, Tilia *Europæa*, and the Tulip tree, Liriodendron *tulipifera:* in others it is deciduous *(decidua)*, or falls with the leaf, which is the most common occurrence; but in this case it occasionally appears withered *(marcida)* before the leaf falls, although it remains attached: and in others again, it remains after the natural fall of the leaf, or is persistent *(persistens)*, as in Downy Sea-side Grape, Cocoloba *pubescens*.

Stipules vary in size, number, form, substance, and situation, in different plants; and these diversities constitute, occasionally, excellent specific distinctions. The presence or the absence of stipules has, also, been regarded as an indication "that "plants belong to the same natural order and even "genus;" but Sir E. J. Smith has justly remarked this is not invariably the case. "Some species of "*Cistus* have stipulas, others none, which is nearly

* "Stipula est squama, quæ basi petiolorum aut pedunculorum enascentium utrinque adstat." *Phil. Bot.* § 84. 1.

"the case with the Grasses *." The diversity of size of stipules in different plants is very considerable; but this circumstance is seldom noticed by Botanical writers. In respect of *number*, they are most commonly twin *(geminæ)*, one being situated at each side of the insertion of the leaf; but in some instances, as the Sun-Rose, *Helianthemum*, they are in fours; and in the Barberry, *Berberis*; in some species of the Honey-flower, *Melianthus*, and in many other plants, they are single *(solitariæ)*. The *form* of the stipule is nearly as diversified as that of the leaf, and it receives the same appellations; thence we find the terms *stipulæ subrotundæ, ovales, lunatæ, sagittatæ, semisagittatæ*, &c. &c. in systematic works, and, consequently, the terms which have been explained, descriptive of the margin, apex, base, surface, as well as those designating the distinct, conjoined, sessile, and petiolated characters of leaves, are applicable to this organ. In point of *substance*, the stipule is termed foliaceous *(foliacea)*, when it resembles the leaf in colour and consistence, which is most usual: membranous *(membranacea)*, when it is thin, nearly semitransparent, and in some degree coloured, as in Amphibious Persicaria, Polygonum *amphibium;* the Magnolia, and Fig tribe, &c.; and chaff-like *(scariosa)*, when it is dry and

* *Smith's Introduction*, p. 220.

semitransparent, as in many species of the Fir tribe, *Pinus;* Knot-grass, Polygonum *aviculare;* Shrubby Cinquefoil, Potentilla *fruticosa*, &c. With respect to *situation*, or *attachment*, stipules are most commonly lateral *(laterales)*, which implies that they stand at the base of the petiole, on each side of it, as in *Passiflora, Lathyrus*, &c.; but the term intermediate *(intermediæ)* is used when their situation is on each side of the stem, between opposite leaves, as in many of the Geranium tribe, and in the Coffee plant, Coffea *arabica.* They are said to be embracing *(amplexantes* vel *amplexicaules)*, when their base surrounds the stem, as in the Mulberry, *Morus;* the Fig, &c.; and sheathing *(vaginantes)*, when they inclose a portion of the stem like a sheath, as in the natural families of *Polygoneæ* and *Rubiaceæ;* in which case they are apparently a mere dilatation of the internal part of the petiole. When the sheathing stipule separates at the top from the stem, and forms a projecting border, it is termed salver-shaped *(hypocrateriformis)*, as in the Oriental Plane (see *d. d.* cut p. 460); Persicaria, Polygonum *orientale*, &c. When the attachment is upon the petiole itself, it is either marginal *(marginalis—petiolo adnata)*, resembling a membranous border extended along the sides of the petiole, as in the Rose tribe (75. p. 515), the Cinquefoils, the Pepper Plant, Piper *nigrum*, &c.; or intrafoliaceous *(intrafoliacea* vel *intrapetiolaris)*,

which implies that it is situated between the stem and the petiole, with which it is united at the lower part only, as in common Clover, Trifolium *pratense*; or extrafoliaceous *(extrafoliacea)*, when it is the reverse of the former. When stipules are situated at the basis of the secondary footstalks in compound leaves, as in Chinese Dolichos, D. *sinensis*, and Hedysarum *gyrans* (97. p. 523), they have been termed *stipellæ* by M. Decandolle; but the distinction is superfluous. The *ramenta* of some authors; the *ochrea* of Rottball*; the *ligula* or *membrana foliorum* of the old writers, which is a white membranous fringe, that crowns the sheathing part of the leaf, encircling the culm in many grasses; and the *sheath*, which covers each leaf before it is evolved, in some plants, as exemplified in the genus *Liriodendron*, and the Magnolia tribe (see cuts p. 474), are stipules. I have already described the peculiar function of this sheath (p. 475): with regard to the functions of stipules in general, little is known, although in some instances they supply the place of the leaves: thus the Yellow Vetchling, Lathyrus *Aphaca*, has one or two pairs of real leaves only on the seedling plants, which soon disappear, and their place is afterwards supplied entirely by the stipules †. Like some other parts of the vegetable body, the

* *Willdenow's Principles of Botany*, § 51.

† *Smith's Introduction*, p. 221.

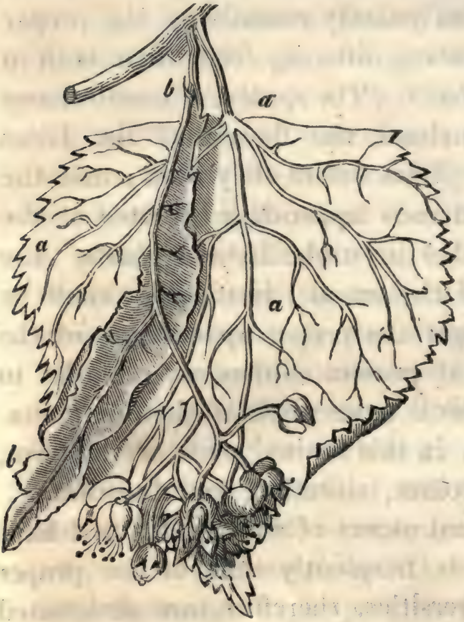
stipule is also liable to undergo transformations: it becomes a tendril in *Smilax,* and a prickle in the *Acacia.*

*b.* The bracte, or floral leaf *(bractea),* is a foliaceous appendage, which appears in the vicinity of the flower; distinct from the perianth, and in some instances exactly resembling the proper leaves, but in others differing from them both in form and in colour *. The *spathe,* a membranous sheath which encloses the flowers of the Irises and some other plants before they blow; and the *involucre,* a foliaceous appendage situated at the base of the umbel in umbelliferous plants, are modifications of the bracte; but as they shall be described amongst the proper appendages of the flower, I shall at present confine my remarks to those bractes which have more of the foliar character. Bractes, in this limited sense of the term, differ in form, colour, situation, and duration.

The *form* and aspect of the bracte, as I have already stated, is frequently that of the proper leaf; and its diversities, therefore, are designated by the same terms which are employed to distinguish those of the leaf. In some instances there is a gradation scarcely perceptible from the proper leaves to bractes, as in Purple-topped Clary, Salvia *Horminum,* Alpine Bartsia, Bartsia *alpina,*

* "*Bractea* dicitur folium florale cum colore et figura recedit a ceteris." *Phil. Bot.* § 84. 2.

Purple and Common Yellow Cow-wheat, Melampyrum *arvense*, and M. *pratense*, &c.; but the bracte may be truly foliaceous, and yet differ considerably in figure from the leaves of the plant to which it belongs. The Lime tree, Tilia *Europæa*, affords a striking example of the difference




in figure and in aspect of the real leaf (*a.a.a.*) and the bracte (*b. b.*), which, in this instance, is attached to the peduncle of the flower. In Black-berried Honeysuckle, Lonicera *nigra*, the bracte is a scale; and in Atractylis *cancellata* it is spinous. The *colour* of the bracte is often merely a different shade of green from that of the leaves; but in many instances bractes are very beautifully coloured: purple, for example, in Cow-wheat, Melampyrum *arvense*, Dwarf Orchis, O. *ustulata*, Purple-topped Clary, Salvia *Horminum;* blue in Milk Vetch, Polygala *vulgaris;* and bright

scarlet in Bartsia *coccinea*. The *situation* of bractes, in the majority of instances, is on the peduncle or flower-stalk, as in the Lime tree, &c.; but in others, on the stem, either beneath the flower, as in Anemone, in which they are regarded as an involucre *(involucrum)*; or forming a tuft above the flowers, when they are termed coronant *(coronantes)*, as in the Crown Imperial, Fritillaria *imperialis*; tongue-leaved Eucomis, E. *regia*, and the Pine Apple, Bromelia *Ananas*, &c.; and, in several species of Mussænda, they arise from one of the teeth of the calyx. In point of *duration* these organs are either caducous, deciduous, or persistent. The use of the bractes, in the vegetable economy, is very little understood. When they have the aspect and colour of leaves, their functions are probably the same as those of leaves; and, when they are coloured, they may resemble, in some degree, those of the petals of the flower; for, in plants which have the bractes beautifully coloured, there is either no distinct evolution of the corolla, as in *Buginvillea*, or the uppermost flowers do not expand, as in Melampyrum *nemorosum* and *cristatum*. Their use to the systematic Botanist, in furnishing characters for the distinction of species, is very important.

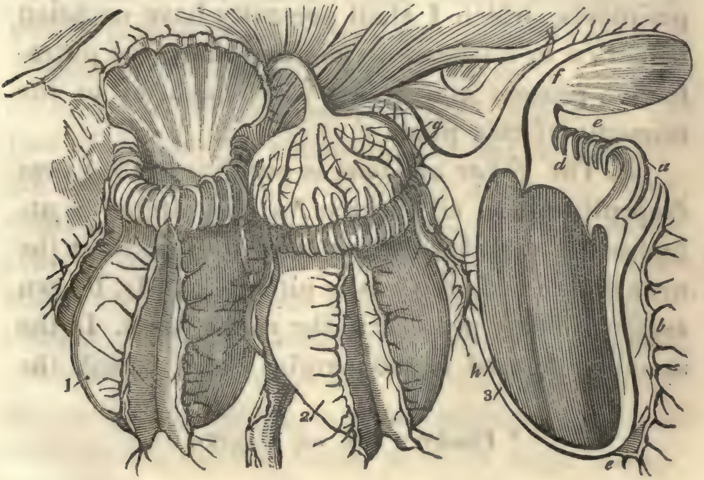
*c.* The pitcher *(ascidium*)* is a hollow foli-

* Willdenow introduced this term from the Greek ασκιδιον, a small bottle.

aceous appendage, resembling, as its name imports, a small pitcher. It is of rare occurrence; but has been found as a *caulinar*, a *foliar*, and a *peduncular* or *floral* appendage.

1. The only *caulinar ascidium* that is yet known, belongs to an Australasian plant, the Cephalotus *follicularis*, discovered by M. Labillardière, and afterwards found near the shores of Princess Royal Harbour, in the neighbourhood of King George's Sound, in Terra Australis, by Mr. Robert Brown, who has described it in the appendix to Flinders's Voyage (vol. ii. p. 600). This singular vegetable production grows intermingled with the leaves of the plant, forming a circle round the base of each flower-stalk. It is pendent by a curved projecting petiole; but, supported in such a manner, that its cavity is upright. The pitcher itself (1. 2. 3. page 671.) is nearly egg-shaped, an inch in length, and furnished with a lid. It is, exteriorly, ornamented with three double costæ (fig. 1. 2.) proceeding from a crested lip (fig. 3. *a.*). These costæ are projecting with acute pilose margins (*b.*), and extend downwards below the bottom of the pitcher (*c.*). The mouth consists of a ring (*d.*), which gives origin to a number of parallel rib-like processes (*e.*), which are curved inwards over it by their upper extremities. The greater

part of the inside is shining, and of a beautiful dark purple colour. The lid (*f*.), which is produced from the petiole (*g*.), and attached to the edge of the pitcher by a broad base, is slightly pubescent on the outside, smooth within, and of a green colour, painted with broad, branching, dark purple veins (2.). The structure of this organ is said closely to resemble that of the leaf. "The ascidia, or pitchers of Cephalotus," Mr. Brown remarks, "were observed to be in general half filled "with a watery fluid, in which great numbers of "a small species of ant were frequently found "drowned. This fluid, which had a slightly "sweetish taste, may possibly be in part a secre-"tion of the pitcher itself, but *more probably* con-



" sists of rain-water received and preserved in it. " The lid of the pitcher in the full-grown state " was found either accurately closing its mouth (see " cut, fig. 2), or having an erect position, and, " therefore, leaving it entirely open (fig. 1.); and " it is not unlikely that the position of the lid is " determined by the state of the atmosphere, or " even by other external causes*." The sweet taste of the water proves the existence of a secerning power in some part of the interior of the pitcher; and it is this saccharine quality of the secretion which entices insects to enter it; but whether the plant derive any advantage from the decomposing animal matter, that results from their destruction, has not yet been ascertained; although, from the result of some experiments, which I shall presently have occasion to notice in reference to another plant, the putrefactive process may prove very beneficial to the economy of this plant.

2. The *foliar ascidium* is peculiar to the genus Nepenthes. In all the species, the pitcher is attached by a *cirrhose* extension of the midrib at the apex of the leaf, the sessile pitcher, as Mr. Brown suggests, being peculiar to the young plant. In the specimen figured in the margin, which is half the

* *Flinders's Voy.* vol. ii. p. 602.


size of the original, the cirrhose wire (fig. 1 *c.*) is elastic, and sufficiently firm to support the pitcher, when full of water, in an upright position. It gradually enlarges as it approaches the pitcher, becoming inflated on the upper surface (*d.*), but remaining flat and firm on the lower; the angles of which gradually terminate in two costæ (*e. e.*), that run up the fore part of the pitcher, and give out branches which pass obliquely across the pitcher, and terminate in the vessels supplying the lid (*a.*). The structure of the cirrhose support is the same as that of the petiole; the proper or returning vessels are very numerous, the spirals are large, and constructed of four flattened threads. The pitcher exactly resembles the leaf in its structure, the whole of the vascular fascicles being prolongations of the petiolar bundles, or branches from the two costæ already described. The coalescence of the fascicles at the back of the pitcher, near the ring of the mouth, forms a third large costa, which is, as it were, inverted, and branches down-

wards. The trunk, also, if it may be so termed, of this costa, which is close to the hinge of the lid, supports a beautiful hook (2. *a.* p. 673), armed with a cartilaginous, acute point; and as this projects backwards, it may afford further support to the full pitcher, by hooking it upon any firm object in its immediate neighbourhood. The lid (1. *a.*) exactly resembles a flat, orbicular, sessile leaf; moveable at its insertion, being furnished with an articulation, or hinge, immediately behind which the hook is situated. But the most curious part of the pitcher is the ring, which distends its mouth. This is apparently a firm, transversely ribbed, thick wire; but is really formed of the lip of the pitcher, which is cartilaginous and transversely striated, rolled outwards like a scroll. It terminates very abruptly at the hinge of the lid, and is larger there than in the fore part of the pitcher.

The pitcher, in the early stage of its growth, is of the same colour as the leaf; but, as it advances in age, it becomes beautifully coloured with dark, purplish red streaks and blotches. Its form in two of the species resembles that of the finger of a glove; but in the third, the *phyllamphora*, it is contracted a little under the mouth and again bulges out below, acquiring thus more of the pitcher shape than the specimen before us displays. It varies greatly in size, and some-

times is capable of holding more than a pint of fluid.

The fluid found in the pitcher of Nepenthes is sweet and limpid; and, according to Rumphius, is the production of the plant. The same author, also, remarks that the waste of it during the day, which is generally about one half, is fully repaired during the night*; but when the lid is completely open the pitcher becomes dry. The pitchers appear dry and withered when they are half full only of water; and, when the dry season sets fairly in, and the seed is nearly ripened, they completely decay. In Amboyna and Java the plant is found on dry, stony, elevated spots only; although in Ceylon it is said to grow in the valleys on the banks of streams.

Phytologists have differed in opinion regarding the cause which produces the opening and the shutting of the lid of this vegetable pitcher. The rising of the lid has been ascribed, by some, to a sudden afflux of fluid rendering the vessels connected with the hinge of the lid turgid; and the shutting to the receding of the fluid. By one

* "Aqua refertus est limpida et dulci, operculo autem "operto, hæc sensim minuitur usque ad dimidiam partem, ita "tamen ut per noctem iterum adcrescat tanta copia, quanta "per diem fuit exsiccata, quum vero operculum totum sit "contractum aqua hæc sensim minuitur fere tota." *Rumph. Amboin.* lib. vii. c. 61.

writer*, however, the rising is ascribed to the contraction of the "fibre," or costa connected with the hinge, "by the hot and dry atmosphere," and the shutting, to its expansion when the air is saturated with moisture; while by others again, these movements are regarded as spontaneous or dynamical, like some other of the movements of plants. In reviewing these opinions the first might be considered probable, as far as concerns the immediate or mechanical cause of the change in the position of the lid, but it does not satisfy the mind; and we naturally inquire, what occasions the afflux and receding of the fluids to this particular set of vessels? for, without an answer to this query, we have gained little by the information afforded us, admitting it to be correct, respecting the state of the vessels. The second opinion is less probable, because we cannot conceive how the costa in question can contract, without producing a corresponding contraction of the whole back part of the pitcher, the consequence of which would, necessarily, be to raise the lip of that vessel to the same elevation as the lid, and thence to place it in the same relative position to that part as it previously maintained. Lastly, the idea of explaining the phenomenon, by saying, that it is a spon-

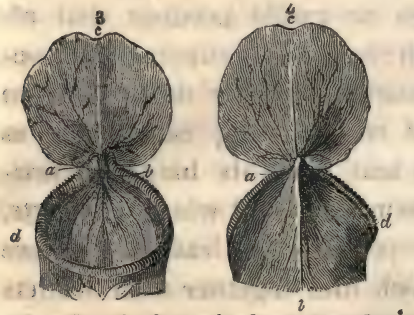
* Mr. Barrow.

taneous movement, either asserts too much, or has no meaning: for if, by spontaneous motion, we do not imply a power of volition in the moving agent, a power I am certainly not prepared to admit as an attribute of plants, we must use some other term to express our meaning.

The deficiency of correct observations on the habits of the plant is, probably, the chief reason why no satisfactory theory of this phenomenon has yet been advanced. Thus, if it had been observed, that the lid opened every morning and closed every night, its elevation might be reasonably ascribed to the stimulus of light, acting on its irritability, and exciting such an increased action of the vessels as would produce that afflux of fluid which has been supposed to occasion its erect position; and its depression, to the withdrawing of this exciting cause: for, as the lid is really a leaf, and its hinge an articulation closely resembling that which connects, with the common petiole, the leaflets of those pinnated leaves which fold together their leaflets at night, we might regard its movements as the result of the same cause which produces the diurnal motions of these leaflets. But we have no evidence that this daily change of position of the lid occurs: we are informed that it opens when the weather is showery and damp as well as at night; and I am disposed to think that the heavy

evening dews, which fall in the climates where the plant is indigenous, are the remote cause of the lid opening at night.

These facts, and a careful examination of the structure of the organ, have led me to imagine that the movements of the lid are entirely mechanical, and depend on a hydroscopic action of the ring forming the lip of the pitcher. We find that this ring (*d. d.* 3. 4.), as I have already stated, is a scroll formed of the lip of the pitcher, rolled outwards: it ends abruptly (3. *a. b.*) close to the hinge of the lid; and is there much thicker, owing to the convolution of the scroll being larger at that part, than in the front of the pitcher. At the




hinge, also, the lid has a small auricle or projection (*a.* 4.) on each side*. Now I suppose that the natural position of the lid is that in which it covers the mouth of the pitcher; and, in a dry state of the atmosphere, it lies close upon the mouth, because the scroll is contracted or closely rolled up, like any other hydroscopic body: but, when

* These cuts show also that the lid is emarginate in front (*c. c.* 3. 4.); and in 4. *b.* we have a view of the costa which terminates in the hinge.

the air is charged with moisture, the scroll swells, and by unrolling itself enlarges the thickness of the ring, and thus produces a pressure upwards and backwards, by which the lid is forced open. I have found, from experiment, that the enlargement of the ring one sixteenth of an inch, would bring the lid nearly into the erect position; and it is evident that the opening of the lid must follow such an enlargement of the ring, unless we suppose that the hinge lengthens synchronously with the unrolling of the scroll, which is not probable. In advancing this explanation, I must allow that it is purely hypothetical, and requires to be confirmed by observations on the habits of the plant in its living state.

With regard to the fluid found in these vegetable pitchers, the most probable opinion is, that it is obtained from the atmosphere, and is intended for the nourishment of the plant; for we can scarcely suppose that so large a quantity of moisture can be thrown out as a excretion, in a plant growing in the dry, sterile situations where *Nepenthes* is found, and for the sole purpose of drowning a few insects*. Rumphius indeed observes, that the insects which crawl into the pitcher all die,

* Sir E. J. Smith supposes these pitchers to be merely fly-traps; and, speaking of the source of the fluid, says it is "certainly secreted through the footstalk of the leaf." *Introd. to Phys. and Syst. Bot.* p. 197.

"except a small *squilla* or shrimp, with a gibbous "back, sometimes met with, which lives there;" but it does not appear that putrefaction goes on in these pitchers, and the constant renewal of the water is, certainly, not favourable to this process.

Another pitcher is the tubular leaf of *Sarracenia,* for it can scarcely be termed an appendage, seeing that it does not issue from a leaf, but originates, directly, from the collar *(collet)* of the plant, which is stemless. In the species before us, S. *purpurea,* the hollow part of the leaf (see 4, page 491) is an infundibuliform, ventricose cavity, almost tubular below, and having a wide open mouth, bounded in the fore part by a revolute lip, and backwards by a broad dilated margin, auricled on each side, and somewhat resembling the spout of an ewer. In two of the species, however, S. *flava* and S. *adunca,* this expanded part of the lip projects forwards over the mouth of the cavity, and constitutes a kind of lid, although not moveable. The lower part of the tube terminates in a thick spongy cord, that ultimately expands to form the part which attaches it to the plant; and the remainder of the leaf is a thin expansion, extending along the whole front of the tubular part. Dividing the funnel or pitcher longitudinally, we perceive that its narrower or lower half is devoid of any proper cutis, and lined

with a reticulated epidermis only, which is studded with long hairs all pointing downwards, and covers a number of glands, the excretory pores of which open upon its surface. The ventricose part of the funnel is smooth, shining, and lined with a cutis closely resembling that of the outside of the leaf; this terminates, however, by a well-defined line a little below the lip; and at the faux, if it can be so termed, of the funnel, we again find a band of the same reticulated, glandular epidermis as at its bottom, except that it is devoid of hairs, and exudes a sweet, viscid secretion. The whole of the interior surface of the dilated lip or hood, is covered with short stiff hairs, all pointing downwards. The pitchers of *Sarracenia* vary considerably in size; some, particularly those of S. *flava*, being often more than three feet in height. All of them contain some fluid. The intimate structure of the whole is the same as that of the leaf.

If the use of the pitchers in *Cephalotus* and *Nepenthes* be problematical, there is sufficient evidence for asserting, that those of *Sarracenia* are chiefly intended for fly-traps; and it is very probable that the gases, and the other results of the putrefactive process, produced by the bodies of the insects which enter them and die there, may be essential to the healthy economy of the plant.

According to some observations on the power of Sarracenia to entrap insects, made by Dr. J.

Macbride, of South Carolina, it appears that the flies, which are attracted to these leaves, first alight upon the faux of the pitcher, and appear to sip, with eagerness, the sweet secretion exuded from the glandular band, which you have seen is situated just below the margin. "In this position they "linger; but at length, allured as it would seem "by the pleasure of taste, they enter the tubes. "The fly which has thus changed its situation, will "be seen to stand unsteadily, it totters for a few "seconds, slips, and falls to the bottom of the tube, "where it is either drowned, or attempts in vain to "escape against the points of the hairs*." Dr. Macbride attributes the fall of the fly to the downward or inverted position of the short attenuated hairs at the faux, on which the fly is unable to take a hold sufficiently strong to support itself; but I am inclined to think that a kind of intoxication is produced in the insect, either by the secretion it sips, or by some exhalation within the pitcher; for I have seen flies, which had fallen, take wing within some of the large pitchers, and again drop before they had reached the faux: and we may infer that this frequently occurs from the humming noise within the pitcher, which is never heard, but when a fly is using the wings. That this seldom occurs in S. *adunca*, the species on which Dr. Macbride made his observations, is probable, be-

* *Linnean Transactions*, vol. xii. p. 48.

cause the faux in this species is covered by the hood, and the light excluded. If the fly attempts to crawl up, the inverted position of the hairs is a sufficient obstacle to its escape. Spiders, a small species of Phalæna, and some other insects which enter these tubes, appear, however, to ascend without difficulty.

I have, already, stated my accordance in the opinion that these putrefying masses may be beneficial to the growth of the plant; but this conjecture, Mr. Keith observes *, "cannot be re-" garded as quite satisfactory till such time as it " shall be shown that the health of the plant is " injured when insects are prevented from ap-" proaching it." It is curious to observe, that these fly-traps become serviceable to some individuals belonging to the very division of the animal creation which they serve to destroy. Dr. Macbride says, " in the putrid masses of " insects thus collected, are always to be seen " one or two maggots in a very active state." He was unable, for some time, to ascertain the insect to which these belonged; " but while watch-" ing attentively some tall tubes of Sarracenia " *flava* growing in their natural situation, a large " fly †," he remarks, " caught my attention: it

* *Syst. of Physiol. Bot.* vol. ii. p. 286.

† This viviparous musca was more than double the size of the common house-fly, had a reddish head, and the body hairy, and streaked greyish. *Lin. Trans.* l. c.

" passed rapidly from one tube to another, delay-
" ing scarcely a moment at the faux of each,
" until it found, as it should seem, one suitable
" to its purpose; then, hanging its posterior ex-
" tremity over the margin, it ejected, on the in-
" ternal surface of the tube, a larvá with a black
" head, which immediately proceeded downwards
" with a brisk vermicular motion." Sir J. E. Smith, also, notices an observation made at the Botanic Garden at Liverpool, which shows that, even in this country, the *Ichneumon* fly employs the pitchers of these plants for a similar purpose. An Ichneumon was, one day, observed by one of the gardeners forcing large flies into the tubular cavity of a leaf of Sarracenia *adunca;* and it is probable, that it had previously deposited its eggs in their carcasses, the eggs of the Ichneumon being often deposited, and the larvæ hatched, in the carcasses of other flies or their larvæ*.

*c. Peduncular ascidium.* This description of organ is rarely found on the peduncle. On Surubea *Guianensis* †, however, we find a small hollow body, connected with a singular forked projection, which rides as it were across the flower-stalk: and a similar body, but without the fork, is observed on the peduncle of Ruyschia

* Some Ichneumons deposit their eggs in the aurelia of moths and butterflies.

† *Aubl. Boyl. Meyer. Fl. Essequeb.* p. 120.

*clusiæfolia* *, and that of Marcgrafia. In these instances, however, the name ascidium can apply to the form only of these organs, as they do not appear intended to hold fluids; and perhaps they may rather be regarded as ascidiform bracteæ than as ascidia †.

vii. *Anomalies.* The only appendage which I shall notice under this head, belongs to a North American plant, Venus' Fly-trap, Dionœa *muscipula;* and it is certainly the most extraordinary production of the vegetable kingdom. The leaf of this plant is radical, sessile, and nearly spatulate in figure (Plate 10, fig. 5. *c.*): the midrib, however, is produced beyond the apex of the leaf, and supports an appendage which has some resemblance to a steel trap. It consists of two lobes, almost elliptical (fig. 5. *b.*), connected together by a whitish, cartilaginous costa, which is, apparently, a production of the midrib of the leaf. The lobes resemble the leaf in colour and consistence, but their margin is somewhat cartilaginous, and furnished with long setaceous teeth, placed at the distance of the tenth of an inch from one another. The superior disk of each lobe is studded with minute glands, and furnished with erect little spines (fig. 5. *a.*), placed so as to form an equilateral triangle, with the apex pointing

* *Jacq. Amer.* Tab. 51. fig. 2.

† They have been termed *Anthocerynium.*

towards the midrib which unites the lobes. To the naked eye, these spines appear like simple bristles; but when they are examined under the microscope, each spine is found to consist of two distinct parts; the one (fig. 6. *a.*), a small cellular papilla; and the other (*b.*), which is supported on its apex, a firm tapering pointed body, resembling a small, inverted bodkin.

This appendage is endowed with so much irritability, that as soon as a fly or other insect alights upon the upper disk of either of the lobes, so as to touch any of the spines, the lobes, if the plant be in a healthy condition, immediately close upon it; and the spines either empale the little animal, or the teeth on the edges of the lobes, crossing one another, prevent its escape, and detain it until it dies.

The anatomical examination of these lobes does not elucidate the phenomenon connected with their functions. They resemble a leaf in their cellular and vascular structure: the vessels being given off from the midrib in arching fascicles, which anastomose, towards the outer margin of each lobe. The epidermis is glandular, and is probably the seat of the irritability of the appendage; but, I have not had an opportunity of examining it with sufficient care, to enable me to determine in what particulars it differs from that of the leaf.

Mr. Ellis, who first described this curious appendage*, imagined that the glands were the irritable parts; and that, as soon as an insect touched any of these, the motion of the lobes was produced. Every other succeeding writer has stated, generally, that it is merely necessary to touch the upper surface of the lobes to excite their action. From a variety of experiments, however, I am convinced that no motion is produced until one or other of the spines be touched; and, from the manner in which these are affixed to the papillæ, and the connexion of the latter with the cuticle of the lobes, I am induced to suppose, that the touching the spines communicates a thrill or tremor to every part of the surface on which they are situated, which excites into action the irritability on which their motion depends. It may be stated as an objection to this opinion, that it is altogether hypothetical; but no hint that can tend to explain so interesting a phenomenon should be withheld.

As the intention of this appendage is evidently

* "The Dionœa was first brought to this country, in the "summer of 1768, by Mr. Young, gardener to the Queen; "and Mr. Ellis described it, and had a drawing and a plate "engraved from a plant which flowered in his chambers in the "following August. It was from this plate and his characters of "the plant, that Linnæus's description was drawn up for his "Mantissa." Vide Smith's *Selection of the Correspondence of Linnæus*, vol. i. p. 235, and vol. ii. p. 72.

to intrap flies and other insects; this question presents itself — what benefit can result to the plant from such a function? We may reply, that there is reason for supposing that the plant derives some advantage either from the putrefaction of the dead insects, or from something which can be obtained from animal matter; a supposition, the probability of which is much strengthened by an experiment made by a Mr. Knight *. Having laid fine filaments of raw beef upon the appendages of a plant of *Dionœa*, he found that this plant was more luxuriant than any other in the same place, although they were all treated alike, with the exception of the supply of beef. That some principle, therefore, is evolved during the decomposition of animal matter, peculiarly favourable to the growth of this plant, is probable, and to secure this, may be the intention of its singular appendages.

An appendage resembling that of the Dionœa, in miniature, is found upon the glume of another North American plant, the Leersia *lenticularis*.

* Mr. Knight was, at the time of making the experiment, gardener to *George Hibbert*, Esq. and is now a respectable nursery-man in the King's Road, Chelsea.

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## CONSERVATIVE ORGANS METHODICALLY ARRANGED.

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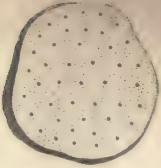
Fig. 1.


Fig. 2.



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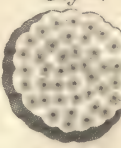

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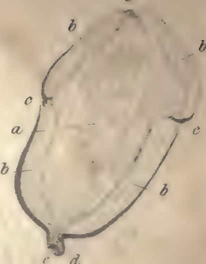


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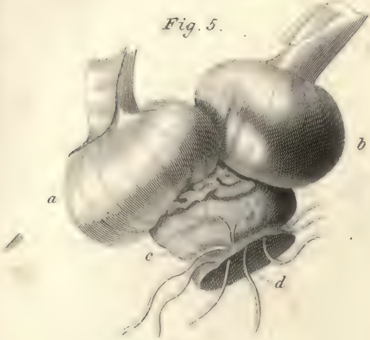


Fig. 6.


Fig. 7.


Fig. 8.


Fig. 9.


Fig. 10.


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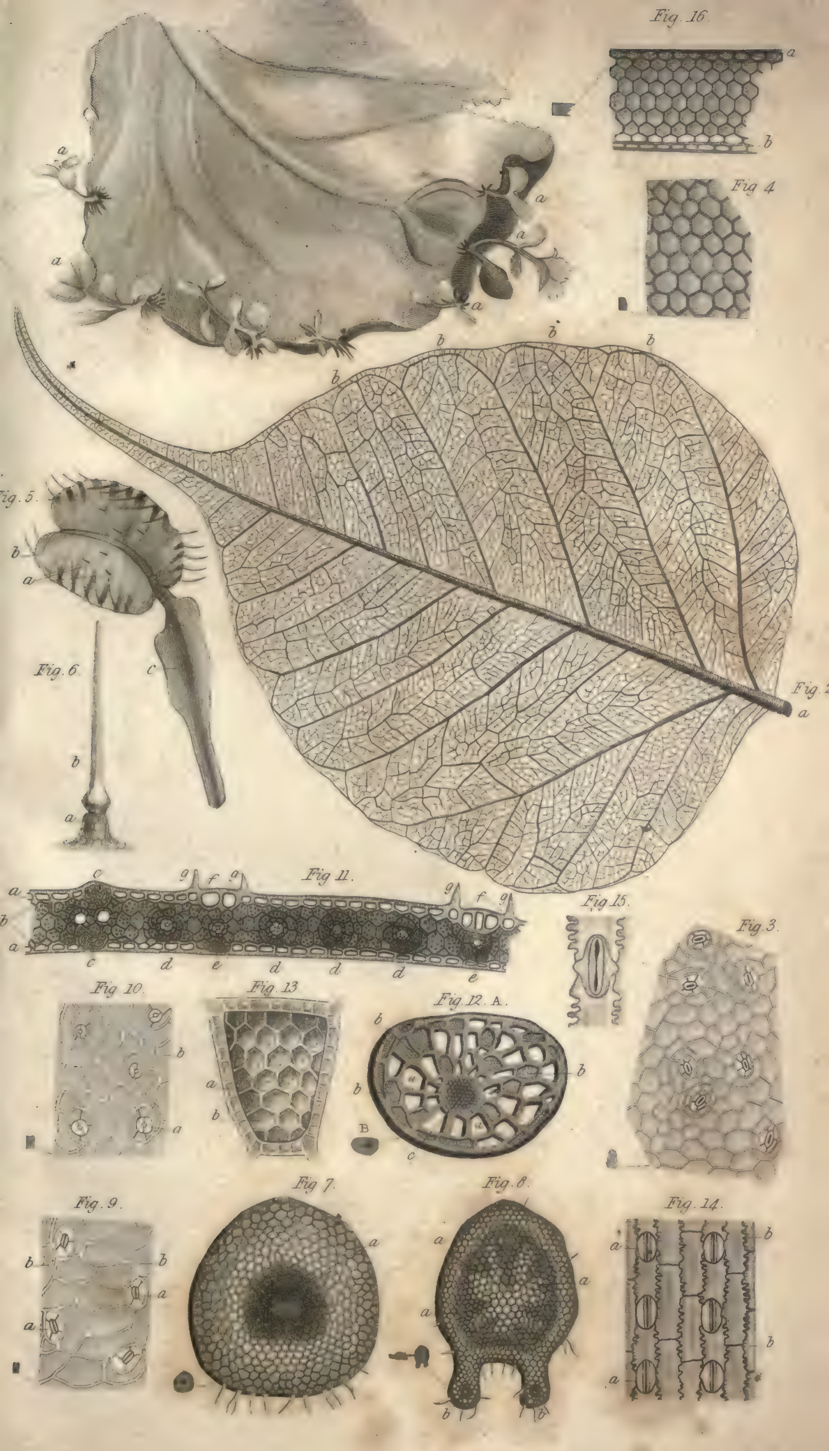


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